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on Canada's Economic Prospects

Canadian Energy Prospects

by John Davis

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ROYAL COMMISSION ON CANADA'S ECONOMIC PROSPECTS

CANADIAN ENERGY PROSPECTS

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JOHN DAVIS

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PREFACE

THE PURPOSE of this study is essentially twofold; to provide factual information concerning the changing market for energy in Canada and, at the same time, to explore the possibilities which further development of the nation's fuel and power resources hold out for the rest of the economy.

Although numerous articles have been written about individual commodities—coal, oil, natural gas and hydro-electricity—few attempts have as yet been made to discuss energy and its implications in broad, economic terms. By describing, in a general way, the multiplicity of demands which the nation's fuel and power industries serve and, at the same time, attempting to highlight some of the more significant effects which future developments in this field are likely to have upon this country's internal and external trade, we have made a start in this direction. It is hoped that in reading this report others will be encouraged to study, and subsequently express their own views upon, this rapidly changing segment of the Canadian economy.

Most of the information has been collected and analyzed over the past 18 months. Individuals in industry and company research departments have been approached with a view to obtaining relevant data and expressions of expert opinion. Interested government departments, Crown companies, specially constituted boards and other public agencies have also been contacted with this end in view. The willingness and care with which these tasks have been undertaken have not only kept our own staff work to a minimum but also added materially to the substance of this report.

A number of people have been engaged, full or part time, in its preparation. Mr. S. W. Clarkson has been responsible for the analysis and presentation of much of the statistical information upon which this study is based. Mr. J. P. Lounsbury and Mr. E. C. J. Westbrook have contributed supporting memoranda dealing with regional and national trends in energy consumption. Mr. R. B. Toombs, besides editing certain technical sections has concerned himself with cost comparisons and the financing of the oil and gas industries in Canada. The charts and other illustrations were drawn by Mr. D. C. Johnson.

Others—all of them prominent men and authorities in their fields—have been consulted. Usually they were asked to read parts of the study

in its near to final form and to provide the Commission's staff with editorial comment. In so far as possible their views were therefore taken into account in preparing the final text. Among those who contributed in this way were: General A. G. L. McNaughton, Chairman of the Canadian Section of the International Joint Commission; Mr. N. B. Guyol, formerly of the United Nations Secretariat; Paul W. McGann, Chief Economist, United States Bureau of Mines; Sam H. Schurr, Director, Energy and Mineral Resource Studies, Resources For the Future, Inc., Washington; Philip Mullenbach, Director of Research, Project on the Productive Uses of Nuclear Energy, National Planning Association, Washington; Dr. G. H. Daniel, Under-Secretary of the United Kingdom Ministry of Power; W. J. Bennett, President, Atomic Energy of Canada Limited; Dr. R. L. Hearn, formerly Chairman of the Ontario Hydro Electric Commission; Mr. G. L. Knox, formerly President of the Canadian Petroleum Association and Dr. G. S. Hume, formerly Director-General of Scientific Surveys, Department of Mines and Technical Surveys, Ottawa.

This Commission, I know, would also like to express its appreciation for the considerable interest shown and assistance given by numerous others including Mr. S. Dorst, Mr. N. B. Hutcheon, Mr. W. S. Preston, Mr. R. M. Crockett, Mr. C. L. O'Brian, Dr. W. B. Lewis and Mr. R. J. Loosmore, with a view to improving both the factual content and readability of this report.

John Davis

Ottawa,
January, 1957

SUMMARY

WHILE there appears to be a close and continuing relationship between energy consumption and economic growth, it does not necessarily follow that an abundance of energy resources will result in a high level of economic activity. With few exceptions, countries reporting a high per capita usage are among the most productive. Putting energy to work intensively, they are also the ones enjoying the highest standard of living. Many of the world's fuel and power exporting regions, on the other hand, are well down the income scale.

The conditions under which energy is made available are themselves among the major determinants of consumption. Continuity of service is vital. Qualitative considerations, while less important than they were, are also essential to the launching of certain types of economic activity. A ready supply of coking coal is required for the production of steel. Natural gas is preferred in certain applications where cleanliness and ease of control are important. Energy in the form of electricity is in demand in a growing number of electro-chemical and electro-metallurgical plants. Price, in that it is often a reflection of the scale on which major new projects are launched, is also a significant factor influencing industrial location.

Canadian experience, in some ways, is unique. Few other countries spend more of their income on fuel and power. Total outlays on this account are presently in the order of 10% of the nation's total output of goods and services. The corresponding figure for the United States has for many years ranged between 6% and 7%. The quantities of energy used in both countries are about the same per unit of Gross National Product (G.N.P.). The difference, therefore, is primarily one of price. Even now consumers in this country are paying up to 50% more for their energy than consumers in the United States.

There is some evidence that the gap is narrowing. Fuel costs are falling throughout western Canada. Also further economies in transportation promise to reduce the market price differentials which have traditionally existed between eastern Canada and most other fuel consuming areas on the North American continent. Though this tendency may to some extent be offset by increased consumption in the more energy intensive sectors of

the economy, outlays on fuel and power may be down between 10% and 20%, *i.e.* to between 8% and 9% of Canadian G.N.P., in 1980.

Meanwhile the demand for energy, as measured in physical terms (such as British thermal units or tons of coal equivalent), is expected to rise at a rate somewhat less than that of the nation's total output of goods and services. Should the Commission's forecast rate for the growth of G.N.P. of 4.5% compounded annually be realized, energy consumption in this country may be expected to rise at a yearly rate of closer to 4%. The former may approximately treble over the next quarter century. During the same period Canada's total requirements for coal, oil, natural gas, fuelwood, hydro-electric and nuclear energy may rise to approximately 2.8 times its present level.

During the period between now and 1980 the strongest demand will come from the industrial sector. Manufacturing, and especially primary manufacturing, may lead the way. The amount of energy devoted to industrial purposes may rise from less than 23% to well over one-quarter of the total during the next two to three decades. The amount of energy used up in energy production and conversion may mount from around 9% to over 12%. Non-fuel uses, including the production of petrochemicals and metallurgical coke, may also show a relative increase. Meanwhile the quantities devoted to transportation and space heating may fall relative to total Canadian consumption.

The Changing Pattern of Energy Use
(each use as a percentage of total energy consumed)

Consumption Sector	1926	1953	1980
Energy industries	7	9	14
Manufacturing and mining	18	23	29
Residential and commercial	37	30	21
Transportation	29	29	26
Non-fuel uses	3	5	8
Other (waste and unaccounted for)	6	4	2
Total	100	100	100

Varying as to end use, these new requirements also call for a greater contribution to be made by the liquid fuels. Twenty-five years from now, oil and natural gas together may supply about 70% of Canada's total energy needs. The contribution made by water power may remain relatively unchanged; that of coal and fuel wood decline. Depending upon further advances in technology, nuclear power plants might also supply 2% or more of the total in the form of electricity and process heat a quarter of a century from now.

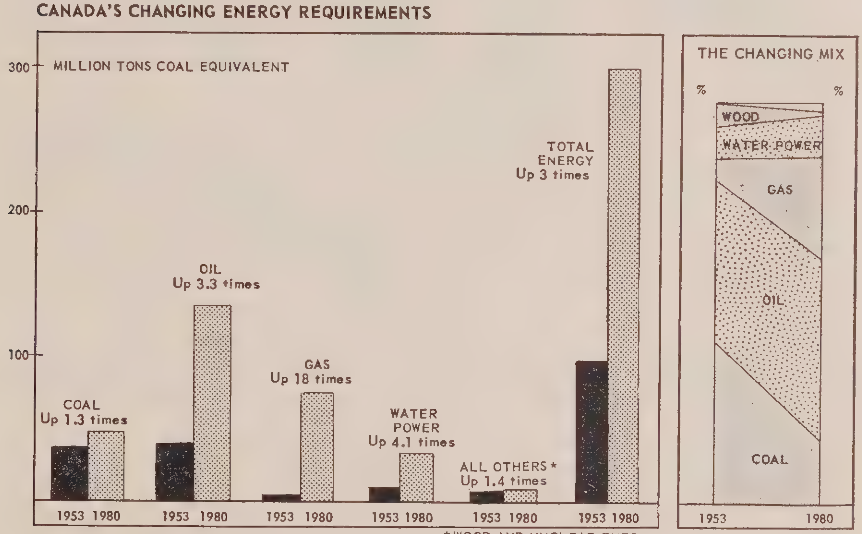
Canada's Changing Energy Supply
(each source as percentage of total energy)

Energy source	1926	1953	1980
Coal	69	39	16
Petroleum	10	42	45
Natural gas[a]	2	4	25
Wood	16	7	1
Water power[b]	3	8	11
Nuclear energy[b]	—	—	2
Total	100	100	100

[a]Including natural gas liquids.
[b]Measured in terms of its contribution as electricity.

Expressed in quantitative terms, a somewhat different picture emerges. The contribution of natural gas may rise eighteen fold; water power four times; oil, more than three times and coal, though down relatively, may still be up by as much as one-third on a tonnage basis. (See accompanying chart: Canada's Changing Energy Requirements.)

CANADA'S CHANGING ENERGY REQUIREMENTS



Of Canada's growing coal needs, well over one-half will be required for the generation of electricity in Southern Ontario. This additional energy will have to come from the United States. Much of the demand for crude oil and imported products in Quebec and the Atlantic region will doubtless be met by shipments from the United States, the Caribbean area and, to a lesser extent, from the Middle East. On the other hand, most if not all of the nation's increased consumption of natural gas and hydro-electric power will be met from sources indigenous to this country.

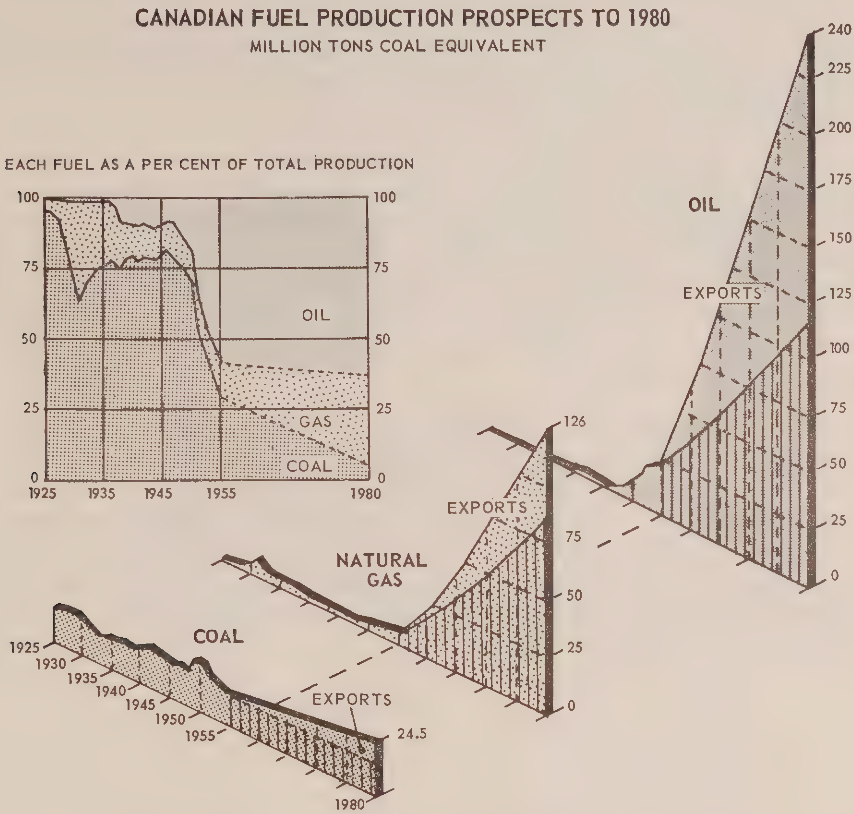
The contribution of wood as a fuel will constantly diminish. Nuclear energy, meanwhile, may appear on a commercial scale, the first plants being built to produce electricity in South Ontario and possibly the Maritimes and Southern Manitoba. Like hydro-electric power, nuclear energy can be put to work more efficiently than can the liquid fuels or coal. Its effective contribution, in other words, will be somewhat larger than the 2% supply figure indicated above. Twenty-five years from now water power may (after due allowance has been made for transmission, transportation and utilization losses) meet over 20% of the nation's energy needs. Nuclear power plants could provide 4% or 5% of the energy actually emerging as effective work in 1980.

It may be that unforeseen technological advances could make nuclear produced electricity competitive at an earlier date than that envisaged here. Yet Canada is endowed with other forms of energy which in most areas are both plentiful and relatively inexpensive to develop. Other countries including the United Kingdom, Western Germany and Japan are in a less fortunate position and consequently nuclear energy will tend to be developed more rapidly there. Because it will become competitive at a later date on this continent, generating plants utilizing this novel source of power for commercial purposes may not be built in large numbers until 1970 or later. In the body of this report it is suggested that one out of every three kilowatts of new generating capacity under construction in 1980 will be of the nuclear variety.

The energy industries are becoming increasingly capital intensive. For this reason, and because their output is expanding much more rapidly than that of the rest of the economy, they will be responsible for a growing proportion of new investment in Canada. Outlays by firms engaged in the discovery, production, transportation, processing and marketing of energy presently account for $1 out of every $7 being spent on the creation of new physical assets in this country. Twenty-five years from now the proportion may be more in the order of $1 out of every $4 invested in the development of new resources and in the purchase of new plant and equipment in Canada.

Canada has never been self-sufficient with respect to energy. As recently as 1950 imports accounted for approximately two-thirds of the nation's fuel needs. Purchases abroad involved an expenditure of foreign exchange of $438 million in 1955. Because Canadian produced oil and natural gas may be used more extensively, this country's dependence on external sources of supply may be reduced to something like 25% of the nation's over-all requirements in 1980. Exports, by then, may exceed imports by a ratio of two to one. Sales of crude oil, natural gas and electricity, principally in the United States, might then exceed the value of imported coal, petroleum and electricity by about $1 billion. Negligible as late as 1955, sales elsewhere could account for between 15% and 20% of Canada's

total commodity exports in 1980. Fuel imports, meanwhile, may decline to around 10% of the value of all goods bought outside the country. (See chart: Canadian Fuel Production Prospects to 1980.)



A complete accounting of Canada's balance of payments with respect to energy also involves allowances for purchases elsewhere of machinery and equipment and payments to non-residents in the form of interest and dividends on foreign capital invested in this country. Though the Canadian content of the fuel and power industries' investment programme will increase and Canadian investor participation, with respect to oil and natural gas, could become relatively more important, it is unlikely that the $1 billion surplus on energy commodity account will be more than sufficient to offset a rise in these accompanying demands for foreign exchange during the forecast period under review.

Employment in the nation's energy industries is forecast as rising from 157 thousand in 1955 to between 350 thousand and 400 thousand in 1980. Relative to the nation's total employed labour force this also means an increase from around 3% to closer to 4% of Canadians with jobs 25 years from now.

As far as new job opportunities are concerned, the greatest gains will occur in processing, distribution and marketing; in other words, in circumstances where the markets to be served are primarily Canadian. Activity generated by the nation's growing export trade in crude oil and natural gas, since it will be confined essentially to exploration and development, will be modest by comparison. Fewer than 30 thousand Canadians will be directly employed in those phases of fuel and power production and transportation which are primarily export oriented.

One of the more comprehensive, and possibly the most descriptive measures of expansion is value of output. Including production for export it will soon approach and eventually exceed expenditures on consumption. The combined value of output of the various energy industries in Canada was equivalent to about 7% of the nation's total production of goods and services in 1955. An aggregation of the accompanying forecasts indicates that their gross value of production may be approximately 13% of the nation's G.N.P. in 1980.

With the exception of water power no serious supply problems are likely to be encountered. Yet, because (a) the energy *producing* section is growing much more rapidly than the rest of the economy; (b) because Canadian produced fuel and power will be entering into international trade on a large scale; and (c) the newer energy commodities are more subject to long-term contracts and government regulation, this complex area of industrial development is likely to become of increasing interest to the Canadian public as the years go by.

Table 1

ENERGY IN CANADA
PRODUCTION, CONSUMPTION AND TRADE
1955 AND 1980

	Coal[a]		Petroleum[b]		Natural gas[c]		Natural gas liquids[d]		Electricity[e]		Wood[f]	
	1955	1980	1955	1980	1955	1980	1955	1980	1955	1980	1955	1980
Production	15	20	354	3,000	190	3000	6	274	81	430	7	3
Imports	20	49	341	500	11	—	3				—	—
								55[g]	neg.	10[h]		
Exports	0.6	5	44	1,600	13	1000	neg.		4		—	—
Consumption	34	64	651	1,900	188	2000	9	219	77	420	7	3

[a]Coal, including lignite, in millions of short tons.
[b]Petroleum, including refinery products, in thousands of barrels a day.
[c]Natural gas in billions of cubic feet.
[d]Natural gas liquids in thousands of barrels a day.
[e]Electricity from all sources in billions of kilowatt-hours.
[f]Wood in millions of cords.
[g]Net movement out of Canada, *i.e.* exports minus imports = 55 thousands of barrels a year in 1980
[h]Net movement out of Canada, *i.e.* exports minus imports = 10 billion kilowatt-hours per year in 1980. (*i.e.* about 2% of production.)

(Table 1 cont'd.)

(A) Energy Reserves in Canada

Petroleum	Year-end	1955	2500 million barrels
	Year-end	1980	13000 million barrels
Natural gas	Year-end	1955	20 trillion cubic feet
	Year-end	1980	70-120 trillion cubic feet
Natural gas liquids			
	Year-end	1955	250 million barrels
	Year-end	1980	4-5000 million barrels

(B) Generating Capacity in Canada
(millions of kilowatts)

	1955	1980
Hydro	13.1	49
Thermal	2.0	21
Nuclear	—	6
Total	15.1	76

(C) Total Energy Consumption, Canada

	1955	1980
Millions tons coal equivalent/year	108	300
10^{12} B.t.u.'s/year	2900	8100

Table 2

RELATIVE IMPORTANCE OF INDIVIDUAL SOURCES OF FUEL AND POWER AND THEIR EFFECTIVE CONTRIBUTION TO THE NATIONAL ECONOMY

(1953 and 1980)

Percent of all energy put to effective use

	Coal[a]	Oil	Natural gas[b]	Wood	Water power	Nuclear energy	Total
1953	32	39	5	5	19	—	100
1980	13	34	25	1	23	4	100

[a]Including coke, manufactured gas and electricty produced from coal and lignite.
[b]Including the natural gas liquids.

Table 3

ESTIMATED VALUE OF PRODUCTION OF CANADA'S FUEL AND POWER INDUSTRIES

(1955 and 1980)

Value in $ millions[a]

	Coal wood, etc.[b]	Oil and gas[c]	Electric power[d]	All energy industries	Percent Equivalent G.N.P.
1955	215	1,070	600	1,885	7
1980	300	6,700	3,250	10,250	13

[a]Expressed in 1955 constant dollars.
[b]Including the production of coke and manufactured gas and wholesale and retail marketing.
[c]Including exploration and development, transportation, processing, distribution and marketing.
[d]Including an allowance for production in industries generating electricity for their own use.

Table 4

ESTIMATED EMPLOYMENT IN CANADA'S FUEL AND POWER INDUSTRIES

(1955 and 1980)

Employment in thousands of persons with jobs

	Coal, wood, etc.[a]	Oil and gas[b]	Electric power[c]	All energy industries	Percent of National total	Percent of All industry[d]
1955	60	63	34	157	3	7
1980	30	217	120	367	4	9

[a]Excluding transportation but including an allowance for distribution and marketing.
[b]Including exploration and development, transportation, processing, distribution and marketing.
[c]Including an allowance for employment in industries producing power for own use.
[d]Mining, manufacturing, utilities and wholesale and retail trade only.

Table 5

ESTIMATED VALUE OF NEW INVESTMENT IN CANADA'S FUEL AND POWER INDUSTRIES

(1955 and 1980)

Value in $ millions[a]

	Coal, wood, etc.[b]	Oil and gas[c]	Electric power[d]	All energy industries	Percent of National total	Percent of All industry[e]
1955	11	494	425	930	14	25
1980	32	2,718	2,050	4,800	25	40

[a]In constant 1955 dollars.
[b]Excluding transportation, distribution and marketing.
[c]Including exploration, distribution, development, production, transmission, refining and marketing.
[d]Including allowance for investment of firms generating electricity primarily for own use.
[e]Total Canadian investment exclusive of government and housing.

Table 6

ESTIMATED VALUE OF TRADE IN FUELS AND ELECTRICITY CANADA, 1955 AND 1980

Value in $ millions[a]

	Imports[b]		Exports[c]	
	$ millions	Percent of total	$ millions	Percent of total
1955	497	10.9	58	1.4
1980	1,050	10.0	1,850	16.9

[a]In constant 1955 dollars.
[b]Valued at point of entry.
[c]Valued at source; *i.e.* excludes value added by transportation in Canada. Were allowance to be made for this service the value of energy exports in 1980 might be in the order of $2,250 million.
[b-c]Trade in each case refers to commodity trade only.

PART A

ENERGY AND ECONOMIC DEVELOPMENT

1

GENERAL INTRODUCTION

ENERGY and industry, industry and energy—to many people, and particularly those concerned with the beneficial results of industrialization, these terms are synonymous. In some ways they are right, for it is inanimate energy in one form or another which lights the factories, generates the steam, melts the metals and turns the wheels of industry, thereby multiplying man's own puny efforts many times over. Then, too, it is the application of energy in the fields of electronics and electro-chemistry which is helping, more than anything else, to revolutionize the way in which industry is organized. Small wonder that the related questions of availability and cost in so far as they apply to fuel and power, have attracted a great deal of attention among engineers, plant managers and company executives everywhere.

Yet a ready supply of energy has even wider ramifications. Its beneficial effects are by no means confined to the primary processing and more advanced stages of manufacturing. Tertiary activities, and this includes the trades and services, are influenced by the quality, price and other conditions of its availability as well. So much so, that some economists are tempted to use the statistics relating to over-all energy consumption as a rough criterion of the material well-being and progress of the individual countries with which they are concerned.[1]

Whether some such correlation has any validity or not, this much is certain: the energy component of the materials stream has been growing relatively as well as absolutely. Most economies, as they have developed, have devoted a smaller and smaller proportion of their national income to the purchase of raw materials. Energy, however, being required at all stages—primary, secondary and tertiary—has moved upward more or less in line with, and sometimes ahead of, each nation's total output of goods and services.

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[1]See for example S. D. Zagaroff, *National Income and General Productivity in Terms of Energy*: Schweizerishe Zeitschrift fur Volkswirschaft and Statistik, Basal, March, 1955.

Put another way, heat, light, and power are in universal demand. Hence, as each stage of fabrication and servicing becomes more elaborate, so over-all requirements of energy tend also to increase. Consumption of food, wood products, most metals and the majority of industrial minerals is falling behind. But energy, the use of which is spreading and deepening throughout each and every sector of the economy, escapes this limitation. In most countries, it has been found to mount more rapidly than population. Usually, its growth rate is found to approach and occasionally exceed that normally associated with G.N.P.

One of the main characteristics of energy use has been the increasing efficiency with which it has been put to work. Better equipment is continually being devised for purposes of its production, transportation and consumption. All this requires capital. Indeed, the investment requirements of some of the more advanced economies are such as to rival those of such major sectors as secondary manufacturing and housing. The main contribution of these facilities, once they are in place, is to effect a saving in salaries and wages. Employment in the fuel and power industries is not only small measured alongside other industries but, in some of the more resource-rich economies, it is even on the decline. Energy, through extensive programmes of capital investment has, in this way, made possible the remarkable improvements in productivity which have been achieved in many countries over the past half century.

Nowhere more than in North America has the utilization of energy assumed greater significance in this regard. Rarely has technology—manifest in a variety of energy-using machines—made more rapid strides. And in few countries has consumption, both over-all and per capita, reached the levels which have been encountered on this continent.

Climatic conditions, great distances, and a shortage of people have each presented obstacles to increased economic activity which, otherwise, could only have been slowly overcome—if, indeed, they had been overcome at all. Resources of fuel and water power there were in abundance. But at the outset they had little, if any, commercial value. First man had to learn how to put them to work. Then, it became a matter of relative costs in order to make the most effective use of the various forms of energy which were available.

Now, desirous of avoiding the cost and other dislocations which may come about as a result of the progressive exhaustion of the more accessible reserves of fossil fuels, the related questions of adaptability and price are coming more to the fore. Distance is less of an obstacle. Along with greater transportability, the areas of competition of the "newer" forms of fuel and power have been expanding; frequently overlapping. Having shifted from the local to the regional, and from the regional to the national, they now promise to become truly international in scope.

Worldwide comparisons are often invidious; sometimes meaningless. Yet, where energy is concerned, there is much to be learned by comparing the consumption levels and consumption patterns of different countries. In many of the so-called underdeveloped parts of the world, all but a very small fraction of the fuel is used up in catering to the barest of human wants—that of cooking and keeping people warm.[2]

In many western European countries, and to an even greater extent on this continent, industry is the main consumer. Manufacturing and transportation together account for over one-half of the total. Even when we include the other service industries, we find that, in the more advanced countries, the needs associated with every day living are not only small but diminishing relative to total requirements—a trend which can usually be taken as reflecting a rising standard of living.

At one end of the consumption scale, we find the energy-rich and more highly industrialized countries like Canada and the United States.[3] Then, more or less in order, come the United Kingdom, several other countries in Western Europe, Australia and New Zealand. At the other extreme—and this applies to as much as three-quarters of the world's total population—we find a situation similar to that which prevailed hundreds of years ago.

Discrepancies there have always been, but in recent years they have become accentuated. More than anything else they throw into vivid relief the differences which exist between the relatively low standard of living of many of the world's people as compared with a fortunate few. Sometimes an inadequacy of resources has been the cause. More often, and especially in recent years, it has been due to a lack of technical know-how and a chronic shortage of capital—both ingredients which the utilization of energy calls for in unprecedented amounts. Eventually, these difficulties may be overcome. As and when they do we shall witness an equally strong though perhaps delayed upsurge in demand in the less highly industrialized parts of the world. Meanwhile, those nations which are well supplied with the liquid and nuclear fuels will continue to expand their trade in these more transportable forms of energy.

To future generations, the history of man's utilization of the more exhaustible forms of energy may appear to be divided into several great periods or ages. First would come the great span of time in which he was dependent on fuelwood and, to a lesser extent, upon agricultural wastes. This was the case until well into the 19th century. Next would come the era in which coal dominated the industrial scene—that is, up until after World War I. And, finally, would come the period in which the liquid

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[2]It is estimated that in countries like India and China 90% or more of fuel used is utilized in this way. Less than 5% is consumed in industry.

[3]Canada and the United States together, with a little more than 10% of the free world's population, now account for over one-half of its total energy usage.

fuels—petroleum and natural gas—supplied the majority of man's energy needs. Though the lasting supply of these latter types of fuel is still open to question, present indications are that they will continue to play a major role throughout the remainder of the present century.

Eventually, other forms of energy will also become available. Nuclear power will undoubtedly make a growing contribution by way of the production of electricity. Solar energy, directly or in the form of chemicals produced from special agricultural crops, may also make a significant contribution in supplying process heat and driving transportation equipment. Eventually, one of these potential sources of energy may come to dominate the rest but all we can be sure of at present is that they, like the crude oil and natural gas which have been introduced in more recent times, will supplement rather than displace in their entirety the older and better known sources of fuel and power.

Mankind, as we have seen, is now living in the third of these great ages—the age of the petroleum fuels—and one which, if our figures or oil consumption are any indication, may also be of limited duration. Statisticians are fond of pointing to the fact that, on this continent, we have less than 15 years of proven oil production in sight; that our known reserves of natural gas, which have been declining in relation to consumption, now amount to less than 25 years supply; and that North America's established water power resources, if they continue to be harnessed at their present annual rate, will all have been put to work by 1980.

This is an unduly pessimistic way of looking at the problem. Further discoveries of fossil fuels will doubtless be made. These must be allowed for in any reasonable appraisal of future prospects. Also, with further improvements in construction techniques, with a better knowledge of run-offs and topography, and with better river regulation, this continent's hydro resources will be found to be much greater than our presently measured potential. Yet, fuel depletion in some areas and the growing difficulty of obtaining quantity production in others are bound to impose penalties, the cumulative effects of which cannot be entirely offset by further improvements in technology, by the relocation of industry, or by the progressive introduction of entirely new sources of fuel and power.

We can learn a good deal from an examination of long-term trends in production costs. By and large, they have been moving upward. Within the past half century, that of fuel wood has risen sharply. The cost of mining anthracite and the bituminous coals has gone up steadily. So, in recent years, have the exploration and development outlays involved in the finding of each additional barrel of crude oil. Only in the the case of natural gas and hydro-electricity has cost as measured by real prices[4] received at

[4]Real prices differ from current prices in that the effect of inflation is removed. The real price of a given commodity moves up if it rises relative to other goods and services; down if it falls relative to the price of other things.

the source shown a long-run tendency to decline. In this respect even these highly desirable forms of energy have shown a tendency to reverse themselves within the past decade.

Yet, to confine our attention to the conditions of production is to ignore the significant economies which have been effected in transportation, in processing, in distribution, and at the level of ultimate consumption. With the advent of the pipeline, the super-tanker and the high voltage transmission line, outlays on transportation have been falling. In most cases, they have more than made up for the need to carry the newer and more transportable fuels over greater distances to their principal areas of consumption. Distribution costs have gone down as the volume of energy has increased. And, on top of all this, we have witnessed the introduction of more efficient fuel burning and power using equipment. As a result of all these improvements, the average industrial consumer has been paying less, and the ordinary commercial establishment and home-owner much less, for each unit of energy which he has put to effective use. This more than anything else, accounts for the fact that their total outlays on energy, measured in relation to other expenditures, have shown little change from one decade to the next.

Like most statements of a general nature, the foregoing does not necessarily apply at all times and in all places. In the older source areas, and particularly those in which coal has long been the principal source of supply, resource depletion has resulted in cost increases at the production level which, though reduced by improvements in transportation and by the betterment of conversion and utilization efficiencies, have become such as to set an upper limit on a number of lines of economic activity. This has been happening in the United Kingdom and in other parts of Western Europe. It has also been taking place in some of the older oil and gas producing areas of the United States. The harmful effects there have not been so apparent in secondary manufacturing and the trades and services, for their outlays on energy are small in relation to their other expenditures. But they are bound to inhibit the growth of the materials processing industries the great majority of which are dependent upon (and indeed may even have been made possible by) the progressive lowering of fuel and power costs in other and sometimes more fortunate parts of the world.

Canada, being a country whose economy is dependent to a much greater extent than most upon these latter types of industry, is necessarily concerned about the questions of future supply and price. Yet, there are related and, perhaps, even more urgent reasons for placing Canadian energy developments in their proper North American and world perspectives.

Until recently, the more populous regions of this country have been fuel deficient; they have been dependent upon imports; and they have been among the highest cost coal, and gas consuming areas in North

America. Only in the case of hydro-electric power have they enjoyed a competive cost advantage over other parts of the continent. Now, with the discovery of substantial reserves of oil and natural gas on the Prairies, some of these disadvantages have been removed. Western Canada, at least, can look forward to an era of industrial development in which most types of fuel and power are available in quantity and at low prices.

Meanwhile, various deficiencies in respect to oil, natural gas and water power are developing in adjoining areas of the United States. Because of this, there will be a growing opportunity for producers in western Canada to export these fuels, electricity and stored water into the Pacific northwest and middle west United States. In time California and the northeastern states may also provide major outlets for Canadian energy.

These opportunities, together with the added impetus which a continental approach to energy matters would provide to exploration and development must, necessarily, be weighed against other considerations which are more narrowly national in character. The growing energy needs of Canada's other extractive and resource processing industries must be served and served adequately. The continuing need to import coal and oil into eastern Canada must be taken into account. And, besides, there is the tendency, particularly in the natural gas and electric power industries, for the operations of utilities on both sides of the International Boundary to become even more closely integrated. Resources are already being committed long-term contracts written and prices set in the expectation that these interregional and international movements will be perpetuated by government consent and regulation.

All these are matters which call for a thorough understanding of the relationship between energy consumption and economic growth. Being to a large extent interdependent, they also call for a consistent policy in respect to Canada's international trade in fuel and power. It is with this in mind that the following sections dealing with availability, costs and prospective patterns of use have been written.

2

ENERGY CONSUMPTION AND ECONOMIC GROWTH

General

Canada's industrial expansion in the 20th century can be interpreted not only in monetary terms but also by listing the ever increasing quantities of energy being put to use on the nation's farms, in its mines, stores, and factories, and in its homes. With the labour force today only little more than twice as large as that of 50 years ago but with better equipment, improved techniques, and—more significant still—with the help of about five times as much energy, the Canadian economy is turning out about six times as many goods and services as it was producing in 1900.

Scarcely a field of endeavour but has benefited in one way or another from the increased availability of fuel and power. Today a farmer with power-driven equipment can harvest 30 acres of wheat for every acre he could have reaped a century ago, using hand tools. Each paper mill operator is turning out ten times as much newsprint as his forebears did around the turn of the century. To raise a ton of ore, the average miner took about two hours as recently as 1930, less than 50 minutes in 1955. Distance has become less of a handicap. On the railways, the latest diesel electric locomotive is capable of doing five times as much work as its steam driven counterpart at the end of World War II. Space heating costs, relative to other consumer expenditures, have been steadily declining. Interesting parallels can also be drawn in other lines of activity, and everywhere the story is the same. An ever growing supply, a wider range of choice and the continual adoption of more efficient energy-consuming equipment have brought about a corresponding saving in time, effort and money.

Elsewhere, much the same sort of thing has been happening. Only the timing has been different. In the United Kingdom where the Industrial Revolution had its beginnings, indigenous supplies, first of wood and then of good quality coal, were the mainspring which attracted industry and upon which industry grew. Extensive coal deposits were the principal reason for the early pre-eminence of the famous Ruhr Valley in Western Germany.

In the northeastern United States, it was this easily won coal, accompanied in later years by an influx of oil and natural gas, which set the stage for the growth of the most complex, and at the same time the most dynamic industrial heartland which the world has ever known.

If it were possible to give a full account of the more important developments in the realm of energy usage from the time the first steam engine was invented down to the middle of the 20th century, the story would resemble the fantastic. Two hundred years ago, only a few million tons of coal were mined yearly as compared with over a billion and a half tons today. Little, if any, oil was produced before 1850 as compared with nearly four billion barrels a year at the present time. The first hydro-electric power station was built as recently as 1882, whereas today the world's annual output of water power based electricity can be measured in trillions of kilowatt-hours. And natural gas, despite references which can be traced back into ancient history, is a relative newcomer and one whose large scale applications are still confined largely to the North American continent.

What, one might reasonably ask, are some of the underlying factors responsible for this tremendous upsurge in the demand for energy? There can be no denying the fact that the introduction of each new piece of equipment has augmented the demand for energy. This need for more fuel, in turn, has called still more machinery and equipment into play. The effect has been cumulative, and energy, the common ingredient of all these activities, has gone on compounding both as to supply and demand.

That there is a close relationship between energy consumption and economic growth has been known for a long time. It has been apparent in the relatively high rates of usage common to the wealthier countries and it has been reflected in the near parallelism which exists between the mounting quantities of energy used and national income in others. (See accompanying chart entitled Energy Consumption vs National Income, 1952.) More recently it has been shown that long-run changes in industrial output and fuel consumption are also closely related one to the other. (See accompanying chart: Changes in Primary Fuel Consumption and Manufacturing Production 1929-55.) There are strong grounds, therefore, for taking the statistics on energy consumption to be a quantitative measure of economic progress.[1]

Once having said that these relationships exist, one must hasten to add that they are not everywhere apparent. They are frequently obscured by various factors—factors including the use of non-commercial[2] (and there-

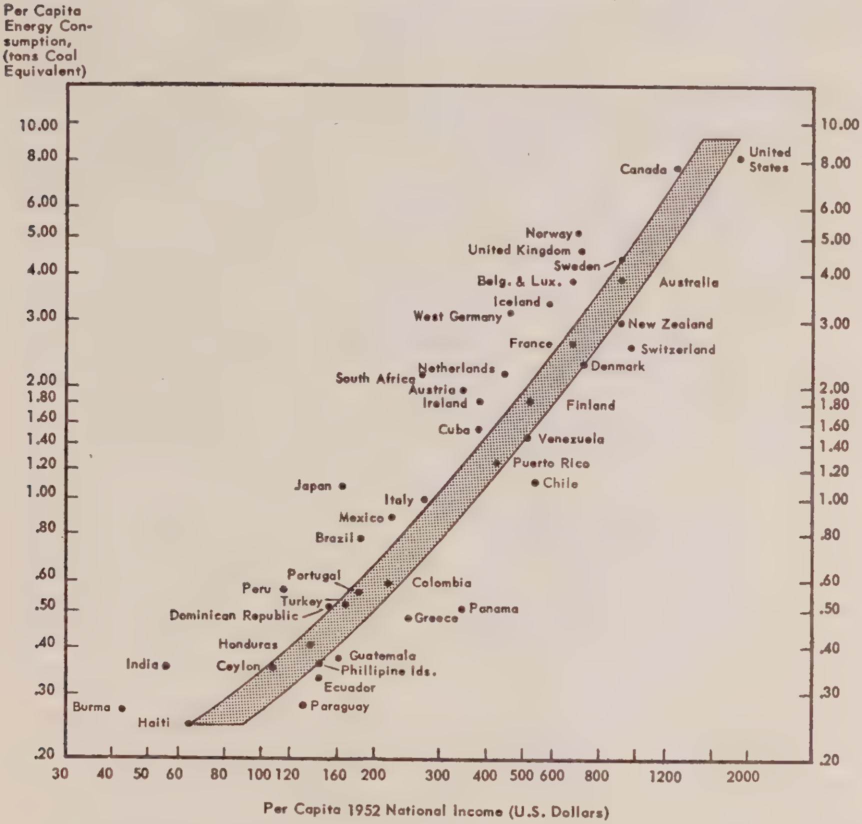
[1]A recent examination of the relationship between energy consumption and economic growth suggests that, for the world as a whole, each 2% increase in energy consumption has been accompanied by a 3% per annum rise in industrial output. (See *The World's Needs for a New Source of Energy* by E. A. G. Robinson and G. H. Daniel, Geneva Conference on the Peaceful Uses of Atomic Energy, Geneva, 1955.)

[2]*i.e.* fuel wood, wood wastes, agricultural materials and animal muscle power.

fore not adequately recorded) sources of energy; changes in efficiency due to the switching from one type of fuel or power to another; and losses involved in converting energy to its more highly processed forms, particularly electricity, coke and the higher priced oil refinery products.

In the case of a relatively underdeveloped country shifting from the use of wood and agricultural wastes to the fossil fuels and water power, a

ENERGY CONSUMPTION versus NATIONAL INCOME, 1952

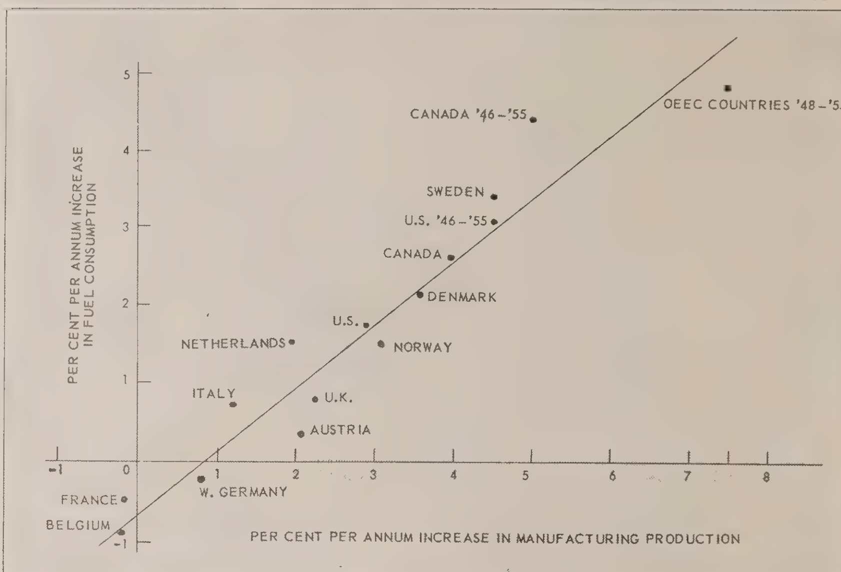


Source: Mason, *Energy Requirements and Economic Growth*, National Planning Association, Washington, 1955.

rapid rise in measured energy consumption can be misleading. Displacement of the older forms must sooner or later come to an end. When it does, the demand for energy will appear to moderate. Fortunately for those of us who have been concerned with an assessment of future Canadian requirements the "commercial" forms of energy already supply close on 95% of demand. This renders less serious the fact that our estimates as to fuel wood consumption may be in error to the extent of 20% or even 30%.

Then there are the complications introduced by a changing fuel mix. The solid fuels, including coal, are frequently less efficient in use than are oil, natural gas and hydro-electricity. Less raw energy in the latter forms will do the same amount of effective work. Conversely, an expanding economy which is at the same time switching over to the use of the more efficient fuels may appear to need less energy to produce a given increment of goods and services. Canada, being in the midst of such a transition, is requiring less additional energy each year than would be the case had its pattern of fuel supply remained comparatively static.

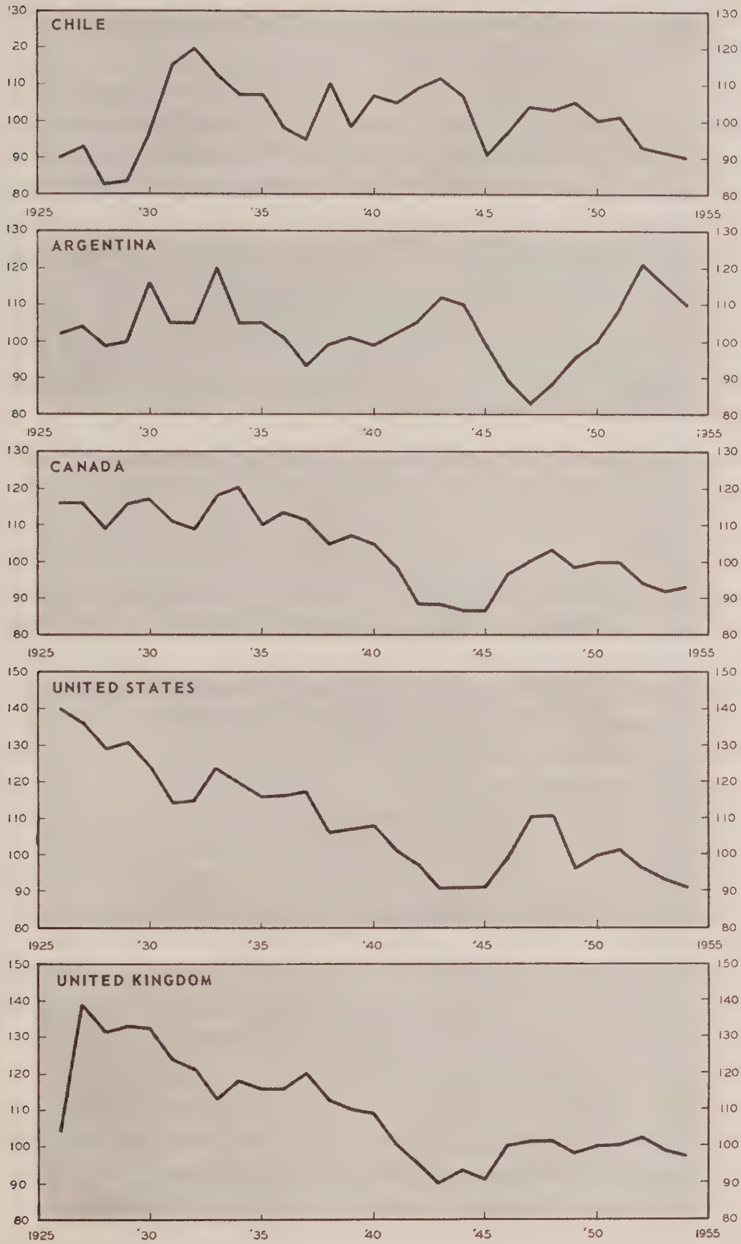
CHANGES IN PRIMARY FUEL CONSUMPTION AND MANUFACTURING PRODUCTION 1929–1955



Meanwhile most forms of energy are becoming more highly processed prior to ultimate consumption. Coal is being converted more to coke, manufactured gas and thermal electricity. Higher octane gasolines and a greater variety of middle distillates are being produced from crude petroleum. Fewer of its heavier ends can properly be called residual oil. Even natural gas is subject to a measure of processing after it is recovered in the field. This too calls for the use of energy; so much so that the energy lost or otherwise consumed in these conversion processes has become comparable in amount to that used for the propulsion of motor vehicles.

What this means in respect to a country like Canada is not always clear. Conversion losses at one level usually obviate undue waste at another. Oil, specially refined, has made possible the diesel engine. A 10% refinery loss has, in this case, resulted in a 400% improvement in locomotive efficiency. This represents a tremendous gain. Yet there are instances of an opposite kind. Coal or any of the other fossil fuels used directly for

INDICES OF ENERGY CONSUMPTION
PER UNIT OF NATIONAL PRODUCT
(1950 = 100)



space heating can be employed to greater advantage than were it first to be transformed into electricity. On balance, however, it would seem that this continual process of upgrading is tending to minimize inputs and maximize outputs. (See accompanying chart entitled *Indices of Energy Consumption per Unit of National Product.*)

Despite these interpretative difficulties—difficulties which apply with even greater force to the more mature economies—certain broad generalizations can, in fact, be made. Energy consumption, in primary forms, tends to move along more or less in line with G.N.P. (See accompanying chart entitled Indices of Energy Consumption per Unit of National Product.) In a few cases, it has been known to exceed the rate of growth of G.N.P. for a period of years. But in the great majority of cases, as economic development proceeds, it is known to lag progressively behind the total output of goods and services. This relationship adds force to the argument that the increased use of energy yields even greater dividends in terms both of industrial productivity and of national income.

It is to be expected that the extent to which energy is used is dependent, in no small measure, upon the types and relative importance of the industries to be served. This industrial use pattern, in turn, frequently reflects the stage or phase of economic development in which we find ourselves.

A highly simplified model might be used to illustrate what is meant by this. In the early years, being almost entirely dependent upon the agricultural and other primary activities such as fishing and forestry, the energy demands of our hypothetical economy in both total and per capita terms, are low. Then comes the turning point. During the early years of change, as farming, logging, and transportation become more highly mechanized and the on-site processing of resources largely for export becomes characteristic of the area, its energy needs mount rapidly. These happenings, augmented by the high losses characteristic of rural energy distribution systems, tend to accentuate the role played by the energy supplying industries. The total of all energy inputs shoots upward much more rapidly than population. For a time, it may exceed the accompanying output of goods and services. Energy as a cost of production will loom much larger in the over-all scheme of things and its price, quality, and other conditions of availability will, consequently, be more important than at any other stage in the development of our model economy.

Sooner or later, various modifying influences begin to make themselves felt. Secondary manufacturing, though it will frequently be displacing earlier industries of an artisan nature, will require fewer inputs of fuel and power for a given volume of production. Most service industries, too, require less energy per unit of output. They, like secondary manufacturing, are at the same time more highly mechanized and more susceptible to economies of scale. Thus, as energy comes to be used not so much in bulk but more as a medium of activation and control, demand will tend to level

off. Only in respect to road transport, and this applies with particular force to the automobile, are wastefulness in use and a higher level of economic development seemingly compatible one with the other.

Hence, raw energy inputs during this more mature phase no longer keep pace with G.N.P. Assuming no change in real price, outlays on fuel and power also show a relative decline. This is what has been happening in the United States during the past 20 to 30 years. It also may be characteristic of the 1960's and 1970's in Canada when increased efficiencies in use and declining fuel prices relative to that of other goods and services will help to minimize the nation's total energy bill.

These are generalizations and, like most statements of this character, apply but imperfectly to the experience of particular localities, or regions, or countries. Variations are introduced by the existence (or absence) not only of indigenous supplies of fuel and power but of other natural resources as well. Density of population, the need to overcome great distances, and the rigours of climate[3] also have a good deal to do with the relative intensity with which energy is put to work in one economy as opposed to another.

Country by country and interregional comparisons are useful in so far as they help to amplify some of the points which have already been made. The countries of the world have been grouped under three separate headings with this in mind. One includes the older and industrially more mature economies. Another, intermediate grouping takes in countries whose process of industrialization has been confined to the past 40 or 50 years. And the third embraces many if not all of the so-called underdeveloped areas of the world—regions where energy consumption is not only low but has remained comparatively unchanged for centuries.

The first group—the more mature industrial economies—includes the United States, the United Kingdom, most of the countries of Western Europe and a few others like Japan. Accounting between them for over 60% of the world's total energy consumption they exhibit several characteristics which are of considerable help in forecasting. They have a long, established and well documented history of economic growth. Also, their industrial structure has become relatively stable. No longer are sporadic developments in primary manufacturing likely to effect a major change in energy requirements. Instead, secondary manufacturing, distribution and the other service activities—because they tend to grow in much more orderly fashion—make the market analyst's job of looking ahead a much easier one.

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[3]Space heating accounts for a large proportion of total energy used in cold climates. In the United States, it has recently been absorbing over 20% of the total energy supply. The figure for Canada is more in the order of 25%. A similar proportion is known to be used in similarly situated countries, such as Denmark, Norway, Sweden and Switzerland.

Observation leads to the conclusion that in such cases the process of economic growth has become quasi-automatic. Rates of expansion in these economies still vary one from another. Yet, this can often be traced to different rates of population growth, greater worker productivity or to the gradual substitution of one more efficient fuel for another. In the United States, population growth, increasing productivity and a slowly changing fuel mix have, over the last half century, resulted in a long-run 2.5% per annum rise in energy consumption. The cases of both the United Kingdom and France are interesting by comparison. In each country, population increase and productivity gains have been less marked. Traditionally more heavily dependent on coal, they have also had greater scope for improvements in efficiency of use. Since 1900 their average yearly rate of increase in energy demand has been more in the order of 1.5%.

Our second group of countries embraces not only nations but whole regions whose economies are only now undergoing a process of rapid industrialization. Presently utilizing between 20% and 25% of the world's total energy production it includes much of Latin America—notably Brazil, Colombia, Mexico, Argentina and Venezuela. The U.S.S.R. and several of its satellites in Eastern Europe are also in this category. These are all countries or regions which have either attained, or are on the point of gaining considerable momentum in the process of economic growth. They differ from the more mature economies in that the forest industries, mining, primary manufacturing and transport account for an increasing—and in some cases a very rapidly increasing—percentage of total output. Such shifts as are occurring are usually happening at the expense of agriculture. Secondary manufacturing and the service industries have really only begun to grow. Thus, the main emphasis is still being directed towards expansion in the more energy intensive sectors within these lesser known economies.

In most instances national income is shooting upward, both because of rapid population growth and because of the remarkable gains in productivity which are possible at this intermediate stage of development. Figures showing yearly gross product growths in the order of 10% are not uncommon. Even at that, energy consumption, as measured in terms of lump coal, crude oil, raw natural gas and falling water appears to be moving upward more or less in line with, or occasionally ahead of, G.N.P. (Examples of both the mature and younger industrial economies are shown on the accompanying chart, Energy Consumption per Unit of National Product.)

Our third group—the less fortunate countries—comprises those regions of the world where per capita income is not only low but has changed little over the centuries. With the exception of a few expanding enclaves where the necessary material, technological and capital resources exist they have so far failed to disturb the Malthusian balance wherein production, energy requirements and population continue to move closely in step one with the

other. The makings of a cumulative expansion, in other words, have not yet put in their appearance.

North America and most of the countries of Western Europe and of European settlement broke through this barrier during the late 18th and 19th centuries. Japan and the U.S.S.R. did so just prior to World War I. China, India, Pakistan and a number of other Far Eastern countries are making a serious effort to do so at present. Once they are on their way, history shows that the typical curve of energy consumption starts sharply upward. Only when they have progressed through the intermediate stage when primary processing and the emphasis on heavy industry and basic transportation services have shifted more to the secondary and tertiary lines of economic activity are their demands for fuel and power likely to follow a more moderate upward curve.

Effective demand, it can be shown, is a function of many things; of cost, quality, assurance of supply and several other and related conditions of availability. Price, the variety and nature of the energy supplied and the requisite capital to ensure its immediate delivery are also relevant considerations. An attractive market for the products of energy intensive user industries is often a prerequisite of development in new areas. Indeed they are all interrelated, for without markets few energy-consuming projects are in fact financeable. All of the foregoing are therefore conditions which are helping to modify in one way or another the significant relationship which appears to exist between energy consumption, productivity, personal income and national economic growth.

In attempting to trace out certain of these relationships let us begin with energy as an item of cost. Weighed against even the most general measures of economic activity it is appreciable. Total expenditures on fuel and power as a percentage of G.N.P., range anywhere from 6% to 12%, depending upon the year and the country involved. The average homeowner in North America pays out more than 10% of his disposable income for fuel and power. Relative to the revenue derived from most types of transportation it is even larger; between 5% and 20%. Industries vary. Direct purchases of energy may be as low as 1% or as high as 50% of their net value of production. In respect to primary manufacturing they are usually upward of 12%. Energy as a cost item in secondary manufacturing averages out around 3%. In thermal power production it may be as high as 60%. Thus a movement either way in the price of energy often has an appreciable effect upon the economic resources available for the purchase of other goods and services.

Though energy remains an appreciable item of cost, price discrepancies between different areas are narrowing. Developments on the transportation front have in this way helped to annul what was formerly a more important determinant of industrial location. Collier rates fell markedly from the 1870's onward. The expanded use of oil after 1900, with its high B.t.u.

content and its more efficient movement by tanker has also helped to average out geographical differences. The advent of the pipeline, by bettering rail haul costs by about two-thirds, has had a similar impact. Again, the newer fuels have frequently been found in regions which were formerly regarded as energy deficient. This, together with the steady depletion of resources in the more highly industrialized coal-producing countries, has also helped to loosen the ties which at one time existed between coal and the location of most types of manufacturing.

Such a conclusion is not necessarily valid for all industries and all areas. Both primary processing and transportation are heavy users of energy. The former has frequently migrated to its own captive source of coal, hydro power or natural gas. The intention has been to keep costs to a minimum. Were it necessary for such producers to pay the prices commonly encountered in secondary manufacturing, their outlays on energy might be forced upward—not by 10% or 20% as one might ordinarily expect, but several times over. This, in circumstances where expenditures on this account are comparable to those on salaries and wages could well mean the difference between survival and the gradual extinction of the industry concerned.

From this, it appears that there are, and will continue to be, exceptions to the rule. The level of energy costs will continue to be a deciding factor in respect to those using it most intensively. The occasional one, as the real price of fuel or power continues to go down, will choose the market rather than locate close to its principal source of energy. Yet others, like those producing U-235, aluminum, titanium, abrasives and some of the newer electro-chemicals, are bound to benefit from such further improvements which can be made on the side of supply. On balance, and with the prospect of technology adding to the numbers of materials requiring large amounts of energy in their initial production, one would expect their numbers to grow rather than to diminish.

Another condition of availability—and one which is sometimes more important than cost—is that of quality. Suitable grades of coking coal are not everywhere available. Coal—even the higher priced varieties—is among the least transportable of our several forms of energy. A number of industries and particularly those of the metallurgical type are therefore drawn to those comparatively few regions where the better grades of coking coal can be produced in quantity.

In some ways natural gas is also unique. As a raw material it is ideal for the production of ammonia, acetylene and certain other and related organic chemicals. Its principal by-products—sulphur and the natural gas liquids—can similarly be used for the processing of metals or in the production of such chemicals as synthetic rubber and the plastics. North American experience indicates that even when the price of natural gas has been substantially increased by long distance transmission it is still heavily

favoured for such purposes as metal working, the manufacture of ceramics, food processing and high temperature precision work. Also, lending itself more readily to automation than coal or the heavier fuel oils, it can bring about savings in direct labour costs and maintenance which are rarely encountered in gas deficient areas of the world.

Oil and water power, because there are alternatives, no longer provide the same drawing power as coking coal and natural gas. Usually, if they provide an advantage, it is one of price. Oil can be transported anywhere and electricity can now be produced by a variety of means. Frequently transportation costs, and hence location on or close to tidewater, enter into calculations of this kind. Thus, low-cost hydro power sites close to the world's main avenues of transportation are still sought after despite the remarkable improvements which have been made in thermal generation. Crude petroleum and its products, being capable of efficient movement either by land or by water, are perhaps the least likely to offset the cost of various economies which usually stem from a greater degree of market orientation.

Cost and quality are but two of the conditions of availability. Delivery on demand and reliability of supply are others. A readily contractable source of fuel or power can sometimes draw industries to an area which, though boasting undeveloped resources, could not otherwise have made such a sale. Many industries deem long-term contracts of a duration of 25 to 30 years prerequisite to large investments in processing facilities. Not only are they interested in present day costs but, in their calculations, longer run price possibilities must also be taken into account. A subsequent influx of secondary manufacturing and service industries could jeopardize continuity of delivery, or, by being able to pay more, could drive prices upward. It is frequently in an attempt to eliminate, or at least minimize, these influences that some of the heavier fuel and power using industries have continued to move into virgin territory where they would be able to develop and retain under their own auspices a particularly advantageous source of energy supply.

Frequent reference has been made to price. But price is also a measure of demand. Charactistically, the industries which place the heaviest demands on energy are also the most capital intensive. In their case, a great deal of money has to be raised and invested, prior to their earning a return commensurate with that afforded by other types of economic activity. The raising of these funds is anchored in turn to the market prospects for these energy intensive products. Often demand, in their case, must be expressed in the form of long-term contracts or be supported by corporate connections which are likely to ensure a high and continuing level of sales. In other words, product market conditions are themselves important determinants of scale and financial arrangements (hence the cost) at which energy can be made available in this country.

If effective demand is a major determinant of development, home consumption of energy is much more so. The production function is creative of wealth. Yet few among the energy-producing countries or areas are also those which can boast the highest standards of living. Instead it is to those who put energy effectively to work that most of the rewards have gone. In the United States the high energy consuming states are those with the highest per capita income. On the other hand, the energy producing areas, if they are not also sizable consumers, are well down the list. Delaware ranks first; Texas 30th in line on the basis of per capita income. Of the four highest ranking states, none is higher than 23rd as a producer of energy. With the exception of California, the six largest producing states rank 17th, 30th, 39th, 40th and 42nd when their per capita incomes are set down one beside the other.[4] Country by country data confirm this thesis—namely, that to be a producer is, doubtless, useful; to be an effective consumer of energy is far more important in so far as the process of creating wealth is concerned.

From this it follows that Canada, while it will benefit from the search for and development of its energy resources, will be even better off if a growing proportion of its supply of oil, coal, gas and hydro-electricity can be put to work at home.

Canada—a Special Case

Though there are numerous similarities, Canadian experience does not fit readily into the general pattern which has been emerging elsewhere. The demand for energy in this country has been growing at a rate somewhat in excess of the world's average. Its composition as to source of supply, meanwhile, is in a state of flux. Requirements by major end use, on the other hand, are changing more slowly one relative to the other.

Industrial requirements are growing more rapidly than the national average; residential and commercial needs are falling behind. Only recently have the liquid fuels begun to challenge coal as Canada's principal source of heat energy. Water power, long the nation's major source of electricity, is now having to be augmented by thermal means. Canada is also on the verge of becoming a substantial producer of energy for export. These latter developments, because they differ markedly from past happenings, render questionable any method of forecasting which rests exclusively on a projection of past trends.

Compared with most other countries, Canada's occupancy of the middle category of growth has been prolonged. This country's energy requirements have for several decades been growing only slightly less than G.N.P. In this respect Canadian performance has differed from that of many of the

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[4]See: *Peaceful Uses of Atomic Energy*, Vol. I, p. 417 (Sporn; *Nuclear Energy in the U.S.A.*) for a complete list of the states according to per capita income and per capita consumption of energy.

younger and less highly developed economies where energy requirements have tended to outpace economic activity generally. At the same time the Canadian energy—G.N.P. ratio has not fallen either as much or as persistently as has been the case in, say, the United Kingdom.

Measured in energy terms, Canadian experience therefore falls somewhere in between that of the more mature and that of the less highly industrialized but rapidly developing regions of the world. This, on reflection, is as it should be. Primary processing and transportation are still dynamic factors influencing the nation's energy consumption pattern. Furnished with an abundance of natural resources, including water power, this country has continued to be an efficient producer of primary products. The initial manufacture of such basic commodities as newsprint, market pulps, refined metals, abrasives and fertilizers has for several decades contributed materially both to the nation's wealth and its extraordinary demand for energy.

While the needs of the resource processing industries have continued to loom large, the requirements of other major use categories have been changing, one relative to another. Manufacturing, stimulated by World War II, by the postwar import control era and by the post-Korean boom has demanded a larger share of the total supply. Transportation requirements have been more stable, gains in highway and aircraft usage broadly offsetting the relative decline in railway fuel consumption. Space heating has become progressively less important falling from 40% to around 30% of the total market for energy since 1939. Meanwhile the fuel and power supplying industries are now gaining—and gaining rapidly—in importance. Oil production and the generation of electricity by burning coal, oil and natural gas, have introduced demands of a type which were insignificant prior to 1950.

The record of the past three decades, presented in tabular form, is descriptive of the divergent trends.

Canada—Energy Use by Sectors
(each use as percentage of total consumption[a])

	1929	1939	1953
Manufacturing	20	20	24
Transportation	29	27	30
(a) Railroads	19	15	11
(b) Highway	6	9	14
(c) Other	4	3	5
Household commercial	40	42	31
Supplying energy	7	8	10
Other	4	3	5
Total	100	100	100

[a]Excluding non-fuel uses.

The changing energy mix also introduces complications. Substitution of one fuel or source of power for another affects efficiency in use sometimes in one way, sometimes in another. With each passing year coal is supplying less of the total demand for energy in this country. Having largely displaced wood it has recently been losing many of its major market outlets to oil. Natural gas, the use of which is only in its infancy, soon will be vying with all three on a number of fronts. Also, while water power is still gaining both absolutely and relatively in importance, electricity is in such demand that other and thermodynamically less efficient sources are having to be introduced; hence the growing interest in nuclear energy.

A second table dealing with the manner in which Canada's mounting energy requirements have been supplied gives a more accurate indication of the changes which have been taking place over the past 25 years.

Canada's Changing Energy Supply

(each source as percentage of total energy)

Energy source	1926	1939	1953
Coal	69	56	39
Petroleum	10	20	42
Natural gas[a]	2	3	4
Wood	16	14	7
Water power[b]	3	7	8
Nuclear energy	—	—	—
Total	100	100	100

[a]Including natural gas liquids.
[b]Measured in terms of its contribution as electricity.

That today's energy supplies are being used more efficiently than they were in the past, there can be little doubt. Output—that is work effectively done—has been rising more rapidly than G.N.P. As distinct from the supply of raw energy (*i.e.* lump coal, crude oil, falling water, etc.) it is a more accurate measure of the contribution which energy is actually making to economic growth in this country.

Since 1926, inputs as measured in terms of B.t.u.'s or tons of coal equivalent have been growing at an average annual rate of around 3%. G.N.P., between 1926 and 1955, increased at an average annual rate of around 3.6%. (See chart entitled Energy and National Growth, 1926-55.) The amount of energy put to effective use, meanwhile also has been rising at a rate of closer to 4% per annum. Implied by these figures is an average national gain in efficiency in the order of 1% a year.

In this process the substitution of one fuel for another has helped. The choice available to Canadian consumers has been widened considerably over the past 20 to 30 years. Electricity, oil, and now natural gas have become available for the purposes to which they are best suited. More efficient equipment is being installed. Operating temperatures, better control, and

improvements in engineering practice and architectural design, by optimizing plant, have enabled the same amount of energy to do a great deal more work.

Further gains will continue to be made in this direction. With the dieselization of the railways, their energy requirements will be reduced. Many of the nation's older homes, stores and factories, due to deficiency in design, or the use of antiquated equipment are still wasteful of heat energy. Canadian industry, like that of other countries, is still operating equipment which was designed and built two or three decades ago. Replaced by installations which incorporate the latest ideas with respect to the conservation of energy, modernization will continue to reduce what otherwise would constitute a much more rapid drain on the nation's fuel and power resources.

More recently, however, these efforts have yielded diminishing returns. Many of the more wasteful practices have been eliminated. This is particularly true of heavy industry. Innovations which have brought about a two- or even threefold improvement in combustion efficiency are rarely possible of repetition. Perhaps a 50% gain is all that is attainable from now on. This is true particularly of boilers, heat exchangers and most other types of heat transfer equipment. Meanwhile, a number of Canada's larger electric power utilities are having to turn from water power to steam generation. The over-all efficiency of the average hydro system is in the order of 85%; that of most thermal electric systems no better than 30%. Obviously as thermal generation gains relatively in importance its input-output characteristics will also have a marked effect (and in this case a depressing effect) on the efficiency of the over-all national energy system.[5] One can only surmise from this that Canada's raw energy needs will tend to approach (or even exceed) rather than fall markedly behind the rate of growth of G.N.P.

So far, our discussion has been in quantitative terms. It has been concerned with physical quantities of energy (B.t.u.'s) and their relationship with over-all measures of economic activity (*i.e.* G.N.P.) expressed in constant dollar terms. Past value relationships are also worthy of investigation. Expenditures on energy relative to G.N.P. or to the "value added" in individual industries also reveal the close connection which exists between energy consumption and economic growth. They are also useful in that they eliminate such errors as may be introduced by the deflation of current to constant dollars.

Price now enters into our calculations. The higher the unit value of energy the higher must be the expenditures of a given economy or industry relative to its total output of goods and services. Assuming that any two are identical in structure, that which has to pay higher unit prices finds its

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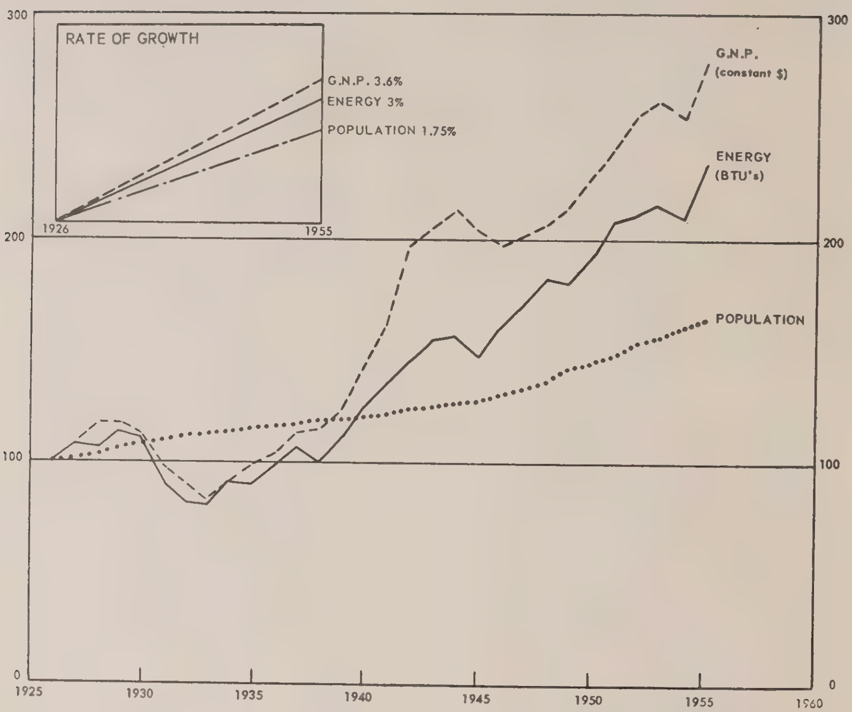
[5]For a further discussion and projection of the over-all Canadian energy input-output relationship see Appendix D.

CANADA – ENERGY AND NATIONAL GROWTH, 1926 – 1955
INDEX 1926= 100



energy bill accounting for a larger proportion of its total value output. Obviously the industry (or economy) which can obtain its energy at lower prices enjoys a real advantage over its competitors.

One interesting measure, though a very approximate one, is the total annual outlay on fuel and power by all consumers of energy relative to G.N.P. In Canada, this is presently in the order of 10%. In the United States it is much lower, under 7%. Such information as is available on Western Europe, suggests that a figure of 7% is currently applicable there. Canadian consumers, if we apply this measure, are therefore devoting a larger proportion of their total effort to the procurement of energy than is the case in most other countries with which Canada engages in international trade.

Several reasons come to mind. Canadians, in combating a more rigorous climate, generally find space heating more expensive.[6] Here the heavier fuel and power demanding industries tend to dominate manufacturing. The ratio of their expenditures on energy relative to total value of sales is therefore higher than in manufacturing elsewhere. Distances being great, transportation requirements tend to exceed the average reported in countries like the United Kingdom. Taxes on fuels like gasoline are higher than in the United States. Each adds materially to the average Canadian consumer's energy bill.

But unit price is even more significant. It has already been observed that the cost of energy, retail, to Canadians is currently equivalent to one-tenth of the nation's G.N.P. As recently as 1939 it was as high as 12%. Since then it has been moving downward. In this respect it parallels experience in the United States. Close to 8% prewar, expenditures on energy as a percentage of G.N.P. in the United States is now running below 7%.

Outlays on Energy vs. G.N.P.

(energy consumption as a percentage of G.N.P.)

Year	1929	1939	1947-48	1952-53
Canada	12.0	12.0	11.5	10.2
United States	7.1	7.8	6.6	6.8

[6]A direct Canada-United States comparison with respect to comfort heating (and cooling) indicates that Canadians do not utilize a great deal more energy for this purpose. Various measures can be taken as proof of this statement. Energy consumption (*i.e.* the number of B.t.u.'s) per dollar of goods and services produced is close if not identical in the two countries. Residential and commercial usage as a proportion of total national requirements is currently about 30% in both Canada and the United States. Since most of this energy is supplied in the form of fuel and electricity for space heating and air conditioning purposes the amounts used in the two countries cannot be far different. Energy usage in manufacturing also exhibits a remarkable degree of uniformity throughout North America. Individual industries, whether they be in Canada or the United States, purchase about the same amount of energy per dollar of output. The processes which they use and the extent of manufacture of the products which they produce are therefore a much more important determinant of the intensity to which energy is put to work.

These figures take on greater meaning when they are set down alongside statistics pertaining to the *quantity* of energy consumed per unit of G.N.P. in the two countries. Per person the output of all goods and services in Canada in 1955 was approximately three-quarters that of the United States. This was almost identical with the ratio of per capita usage as expressed in physical terms. (Canadians now use about three-quarters as much energy expressed in B.t.u.'s as their neighbours to the south.) Were prices to be identical, expenditures on energy divided by G.N.P. would closely approximate one another. Instead, the Canadian figure, as reported in the above table, is 50% higher than that calculated for the United States. Though the margin between the two may be narrowing, it is obvious from the foregoing that the Canadian economy has been at a real disadvantage in so far as the delivered price of energy is concerned.

A map showing the location and extent of the major North American bulk fuel cost zones confirms this view. That shown in Chapter 4 is indicative of the regional price structure which prevailed in 1953. It shows that the majority of Canadian users (and especially those in the areas of greatest industrialization) paid a good deal more for their fuel than the average U.S. consumer. The delivered price, per million B.t.u., in Quebec, the Maritime Provinces and Newfoundland was on a par with the highest encountered anywhere in the United States. The same applied to much of central and northern Ontario, eastern Manitoba and central British Columbia. Only in the western Prairies and, to a lesser extent, southern Ontario, have Canadian consumers enjoyed access to fuel, the delivered price of which is equal to or below the North American average.

This situation is changing rapidly in western Canada; more slowly elsewhere. Prices in British Columbia are falling with the extension of natural gas service to the West Coast. Electric power will also be much cheaper there once large scale developments get under way on the Fraser and Columbia Rivers. Eastern Canada will benefit modestly from the arrival of western Canadian gas. Imported oil will also help to moderate price trends in Quebec and the Maritimes. Since the general trend in real energy prices may be upward in the larger centres of population and industry in the United States, some of the Canada-United States fuel cost discrepancies referred to earlier may be reduced, if not eliminated in their entirety during the forecast period under review.

One of the most reliable (but by no means the only) indicator of the role which energy has played in the Canadian economy is the cost statistics relating to manufacturing published annually by the Dominion Bureau of Statistics (D.B.S.). These can be broken down among fuel, power, other materials, and salaries and wages. Calculated since the mid-1920's, they show energy as an item of cost rising perceptibly in the decade after 1925, levelling off in the immediate prewar years and declining from 1940

onward. Reported in percentage terms and averaged out for five-year intervals over the past 30 years, they run as follows:

Energy Expenditures in Industry

Outlays on Fuel and Power in All Manufacturing Industry as a Percentage of:

Period		All materials purchased	Salaries and wages	Net value of production	Gross value of production
Average	1925-29	4.7	13.0	6.0	2.6
	1930-34	6.0	14.3	6.7	3.2
	1935-39	5.3	14.6	7.1	3.0
	1940-44	4.8	12.3	6.2	2.7
	1945-49	4.4	12.1	6.0	2.5
	1950-54	4.2	11.1	5.3	2.3

From this, several things become apparent: namely, that

(a) the cost of fuel and electricity is smaller in relation to expenditures on other materials than it was in the 1930's; that

(b) the cost of fuel and electricity is smaller in relation to outlays on salaries and wages than it was prewar; and that

(c) energy, as a direct item of cost in most types of industry is comparatively stable. Over the 30-year period since 1925, it has averaged out at around 6% of the value added by manufacturing in Canada.

It is well to recall, however, that energy is usually more important in the early stages of manufacturing. Primary processing—and this applies to a number of Canada's major export industries—still employs considerable amounts of fuel and power. Its effects, however, have been obscured by a steady proliferation of secondary and tertiary activities in recent years. Aimed largely at the domestic market, and involving a greater input of labour and capital, the "value added" in later stages of production has grown both relatively and absolutely. The more primary or more energy intensive processes, as a result, have become less important in the whole fabric of industry. This provides us with one explanation for the relative fall in expenditures on energy. Another, of course, is the gradual decline which has taken place in the unit price of energy itself.

Canada, as we have seen from our other studies, is more dependent than most on the earnings of her primary industries. Food processing, pulp and paper, non-ferrous metal smelting and refining, heavy chemicals, fertilizers and the production of abrasives, alone, account for well over half of the nation's export trade. Their energy cost relationships consequently warrant special consideration.

Proportionately, they are much higher than for manufacturing as a whole. Yet, total expenditure on fuel and electricity, in their case, has also lagged

well behind that of other "purchased" materials. It has fallen by about 25% relative to net value of production; more than 30% as compared with the gross value of sales. Only in respect to salaries and wages has there been little change. This, of course, points up the continual substitution of machinery and equipment for labour. At the same time, the increased amounts of energy to drive the former are available at lower prices than was the case, say, in 1929.

Energy Expenditures in Primary Manufacturing

Outlays on Fuel and Power in Primary Manufacturing[a] as a Percentage of:

Period		All materials purchased	Salaries and wages	Net value of production	Gross value of production
Average	1925-29	21.5	51.3	19.5	10.2
	1930-34	21.7	57.2	21.5	10.8
	1935-39	17.6	66.3	24.9	10.3
	1940-44	15.2	53.5	22.1	9.0
	1945-49	14.0	45.3	18.7	8.0
	1950-54	12.8	48.5	14.6	6.8

[a]Exclusive of primary food processing.

Particularly striking is the fact that, since 1925, expenditures on fuel and electricity have been 50% or more of those devoted to the payment of labour. In the late 1930's, the ratio between the two was more like 2:3. Meanwhile, much larger volumes of other raw and semi-processed materials have been consumed. Their costs were about five times that of energy purchases in the late 1920's as compared with around eight at the present time.

The record of individual industries was also examined during the course of this study. In the case of the nation's pulp and paper mills, total outlays on fuel and power have risen relative to salaries and wages. From 50% in the late 1920's, expenditures on energy have risen to around 65% of that industry's payroll. With regard to non-ferrous metals smelting and refining much the same sort of thing has been happening. Thirty years ago outlays on energy were 52% of expenditures on salaries and wages. Now they total closer to 60%. Fertilizer production as it developed to serve export markets also became more energy intensive. Its outlays on fuel and power have risen from about 8% in the late 1920's to around 20% of the fertilizer industry's total wage bill at the present time. Meanwhile the structure of Canada's primary iron and steel and chemical industries has been moving in the opposite direction. Being more concerned with serving the domestic market they have added more value to their products in the sense of further fabrication and secondary manufacturing prior to consumption. The percentage decline in the case of the primary iron and steel mills has been from 40% to 26% and in respect to basic chemicals

from 65% to 43%. More than anything else, these figures indicate the importance of energy and its progressive substitution for labour in the nation's export industries. Conditions of availability in price are therefore of major importance to this highly competitive sector of Canada's burgeoning economy.

An equally relevant observation relates to the influence of energy on industrial location. As a result of improved methods of transportation, cost differentials have been narrowing. In Canada, the processing of resources has not kept pace with like developments elsewhere. Such pulp and paper mills as have been built tended to go to the forests; new smelting and refining capacity, to the mines. Secondary manufacturing and the service industries have gone to the market. While there are a few exceptions, (*e.g.* aluminum production) such statistics as are available also corroborate the view that the drawing power of sources of cheap energy on manufacturing in general has been weakening.

In this country, fuel and power prices vary considerably from one area to another. So does the extent of industrialization. In order to test the effect of geographical cost differences upon the industrial orientation, consumption data, relating both to volume and value, were compared on a provincial basis for the years 1939 and 1953.

Fuel Consumption in the Manufacturing Industries

Province	1939		1953	
	Million B.t.u.'s per employee	Cost per million B.t.u.'s	Million B.t.u.'s per employee	Cost per million B.t.u.'s
Nova Scotia	1,170	.13¢	603	.46¢
New Brunswick	726	.18¢	743	.46¢
Alberta	695	.12¢	774	.25¢
Saskatchewan	649	.23¢	782	.48¢
Ontario	408	.22¢	397	.49¢
British Columbia	311	.22¢	353	.54¢
Manitoba	298	.23¢	351	.39¢
Quebec	229	.29¢	305	.54¢
Prince Edward Island	129	.28¢	147	.87¢

The results show, quite clearly, an inverse relationship in 1939 between fuel consumption and fuel cost, the coefficient of correlation being –0.84. Since energy is generally required in fixed proportions to other factors of production, this interesting relationship reflects a definite tendency for the fuel intensive industries to locate themselves in low fuel cost areas.

Time, however, has had a modifying effect. The analysis carried out for the latest year for which detailed regional statistics are available—namely, 1953—shows this relationship to be less marked. The coefficient of correlation for that year was –0.68; thus implying that, over the past decade

and a half, energy costs have become a less important factor in respect to the locating of the great majority of industrial establishments.[7]

That there are exceptions has already been noted. The electro-process industries—for example—are much more sensitive to energy costs than is the average for all industry. Certain products—and this includes the higher priced petrochemicals—tend to be produced where natural gas is both cheap and likely to be in surplus supply for long periods of time. Tidewater locations are often favoured because fuel, like other process materials, can be brought in relatively cheaply. To this extent, the costs of energy have continued and will continue to have a significant effect upon industrial location.

On the other hand, with the progressive adoption of chemical methods of treatment, primary processing in both the pulp and primary metal industries has lessened the need for fuel and power as such. Instead, energy has become more desirable in the form of mineral acids or ammonia made from natural gas. Since these reducing, bleaching, or other agents can sometimes be manufactured locally or occasionally supplied in readily transportable form, technological developments on the chemical front may well run counter to those of a more historical nature.

The fact that the delivered cost of energy is declining is having an effect of its own. New products are being thought of commercially whose production cost would have been regarded as prohibitive a decade or so ago. Metals like lithium, zirconium and beryllium are now being manufactured in appreciable quantities. Separation of the fissionable isotope of uranium, U-235, requires electricity in quantities well in excess of that needed to produce either aluminum or titanium metal. Reduction of silicon, because of its relative abundance in nature is also receiving serious study. Numerous other examples can be obtained from a reading of the technical press.

All these are industries which, as they emerge, will of necessity gravitate to the cheapest possible source of fuel and power. To the extent that this happens, they will tend to offset the growing insensitivity of most other types of industry to energy as an item of cost.

Yet manufacturing is only one of the major energy use sectors. Expenditures on fuel and power relative to total revenue also loom even larger in respect to transportation. Though declining on the railways the ratio between the two is still in the order of 8%. In shipping the cost of fuel relative to gross income is in the order of 11%.[8] On the highways, purchases of motor fuel as a proportion of total cost have remained in the

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[7]A similar study carried out for the United States and reported in National Resources Planning Board—*Industrial Location and National Resources*—shows correlations of –0.71 and –0.69 for the years 1939 and 1947.

[8]In respect to shipping the relationship between outlays on fuel and gross income during the postwar period has been as follows: 1946, 9.2%; 1951, 11.3% and 1955, 10.8%.

vicinity of 15% ever since the late 1920's.[9] A similar figure applies to commercial air transport.[10]

Only in the case of the railways has there been any indication of a falling off in expenditures on energy relative to other costs. That this has been due largely to dieselization is apparent from a comparison of Canadian and United States statistics which relate the total cost of railway fuel to total railway revenue over the past 30 years.

Expenditures on Fuel as a Percentage of Total Revenue
(steam railways)

	1925-29	1930-34	1935-39	1940-44	1945-49	1950-54	1954
Canada	9.2	8.8	8.7	8.7	11.0	9.1	7.8
United States	—	—	6.8[a]	6.1	7.3	5.4	4.6

[a]1938 only.

Residential and commercial usage, while it has been falling relative to manufacturing and transportation requirements, may also be regarded as one of the more energy intensive sectors of the Canadian economy. Although precise data are difficult to come by in this field, approximations can be arrived at, based on door-to-door household and other surveys carried out by the D.B.S. These suggest that in 1948 the average family in Canada spent approximately 10% of its disposable income on energy. The latest survey, which pertains to 1953, indicates that currently the ratio of fuel and power to total family expenditures is between 8% and 9%.

The most energy intensive are those utilities generating electricity by thermal means. Power companies employing coal, oil or natural gas as their primary source of energy now frequently spend one-third of their total income for fuel. With the passage of time the ratio between expenditures on energy and revenue obtained through the sale of thermally produced electricity has tended to rise. This is illustrated by the following table.

Expenditures on Fuel as a Percentage of Total Revenue
From the Sale of Thermal Power

	1926-30	1931-35	1936-40	1941-45	1946-50	1951-54	1954
Fuel as a % of total revenue	26.6	21.1	21.4	25.6	32.4	39.6	39.9

[9]This is a more difficult calculation. Outlays on motor fuel were estimated from published data on gasoline production and imports and average annual gasoline prices from 1926 to 1955. These yearly expenditures were then compared with the "direct costs" as reported in the transportation study published by this Commission. The ratios, again expressed in percentage terms were: 1928, 15.3%;1936, 15.4%; 1945, 14.6%; 1949, 18.9% and 1953, 14.5%.

[10]When the total outlays on fuel as reported for scheduled and non-scheduled commercial airlines in Canada are compared with their aggregate operating revenue for the year 1955, total fuel cost, as a percentage of revenue, amounts to 15.3%.

Though it has been possible to trace out certain long-run trends in the use of energy relative to a number of industries and other categories of use, real importance has generally been understated. This is because such measures as gross value of production and total revenue from sales have been employed. As the latter generally over-state the true contribution to the economy of these various industries and other types of activity, the outlays on fuel and power have appeared smaller by comparison. With a view to setting energy in its proper perspective and, at the same time, enabling the reader to obtain a better appreciation of the relative intensity of consumption, use sector by use sector, the following series have been prepared.

Energy Consumption and Income Originating in Various Sectors of the Economy, Canada, 1953[a]

Consuming sector	Energy B.t.u. x 10^{12}		Income originating in millions of dollars		Input coefficient 10^3 B.t.u./dollar
Agriculture, forestry and fisheries	99		3,405		29
Mining	75		857		97
Primary manufacturing	331		1,427		232
Food processing		36		330	109
Wood products		4		262	15
Pulp and paper		163		439	371
Smelting and refining		65		242	269
Non-metallic minerals		35		44	795
Industrial chemicals		28		110	255
Secondary manufacturing	335		4,768		70
Foods and beverages		34		439	77
Iron and steel and its products		66		725	91
Transportation equipment		24		967	25
Textile products and clothing		19		659	29
Non-metallic minerals		29		154	188
Electrical apparatus		6		374	16
Products of petroleum and coal		65		132	492
All other		92		1,318	70
Total manufacturing	666		6,195		108
Elec. power utilities	67		351		191
Transportation	670		1,714		391
Trade services etc. (domestic and commercial)	780		9,448		83
All other	260				
Total economy	2,617		21,970		119

[a]For similar table of the U.S. economy in 1947 see: Mason, *Energy Requirements and Economic Growth,* National Planning Association, Washington, 1955.

It will be seen from the preceding table that there is a wide variation between different sectors of the economy as to the amount of energy consumed per unit of national output. Primary manufacturing is the most

energy intensive though a few secondary industries such as oil refining and coke production are also heavily dependent upon fuel and power. Among the primary industries, the production of bulky low-cost building materials like cement, industrial materials like abrasives, and other primary manufactured products like non-ferrous metals, pulp and paper, and heavy chemicals have the highest input coefficients. The transportation sector is important because it includes automobile gasoline—a substantial energy input which has only a small income equivalent. Agriculture, most types of secondary manufacturing and the trades and services, by contrast, employ much smaller amounts of energy per unit of national product.

Similar observations apply to the amounts of energy purchased per employee. The amount of energy consumed per employee in Canada in 1953 was highest in the production of primary non-metallic minerals followed by petroleum refining, pulp and paper, non-ferrous metals, smelting and refining and industrial chemicals.

Energy Consumption per Employee in Industrial Sectors in Canada, 1953

Consuming sector	Consumption per employee 10^6 B.t.u.
Primary manufacturing	1,162
Food processing	393
Wood Products	44
Pulp and paper	2,801
Smelting and refining	2,590
Non-metallic minerals	7,000
Industrial chemicals	2,060
Secondary manufacturing	340
Foods and beverages	399
Iron and steel and its products	351
Transportation equipment	153
Textile products and clothing	99
Non-metallic minerals	1,000
Electrical apparatus	78
Products of petroleum and coal	3,800
All other	310
Agriculture, forestry and fisheries	102
Mining	815
Total manufacturing	502
Elec. power utilities	1,314
Transportation	1,580
Trade services etc. (domestic and commercial)	336
Total economy	505

In carrying out this study statistics pertaining to energy production and consumption were also prepared by provinces. Listed for 1955 they generally confirm the earlier observations appearing at the end of the previous section, namely:

(a) that regions with high per capita income with few exceptions are those also reporting a high per capita usage of energy; and

(b) that substantial producers of energy are not necessarily at the top of the income scale.

Energy and per Capita Income, Canada, 1955
(by province)

Province	Personal income		Energy Consumption		Can. energy production	
	Per capita	Rank	Per capita	Rank	Percent	Rank
Canada	1,262		189		100.0	
Ontario	1,521	1	190	2	7.0	5
B.C.	1,505	2	165	3	4.0	6
Alberta	1,244	3	290	1	59.0	1
Manitoba	1,158	4	110	8	3.0	7
Saskatchewan	1,147	5	130	7	7.0	4
Quebec	1,098	6	135	6	8.0	3
N.S.	949	7	155	4	10.0	2
N.B.	828	8	145	5	2.0	8
Nfld.	667	9	90	9	0.2	9
P.E.I.	657	10	90	10	—	10

Table 7

COST OF ENERGY IN MANUFACTURING INDUSTRIES IN CANADA, 1953

(money figures in thousands of dollars)

Industrial group	Value added by manufacturer	Cost of fuels and purchased electricity	
		Total	% of value added
Foods and beverages	1,146,474	48,748	4.2
Tobacco and tobacco products	75,015	638	.8
Rubber products	172,674	3,725	2.1
Leather products	103,937	2,067	1.9
Textile products (except clothing)	299,231	13,134	4.4
Knitting mills	81,264	1,823	2.2
Clothing	333,239	2,391	.7
Wood products	577,382	14,902	2.6
Paper products	767,274	83,517	10.9
Printing, publishing and allied industries	364,364	4,166	1.1
Iron, steel products	1,140,931	51,454	4.5
Transportation equipment	961,205	17,779	1.9
Non-ferrous metal products	458,180	57,702	12.6
Electrical apparatus and equipment	457,490	6,957	1.5
Non-metallic mineral products	239,816	34,974	14.6
Products of petroleum and coal	211,553	35,225	16.6
Chemicals and allied products	448,277	29,541	6.6
Miscellaneous industries	154,763	3,052	1.9
All manufacturing industries	7,993,069	411,795	5.2

Table 8

COST OF ENERGY RELATIVE TO OTHER ITEMS OF EXPENDITURE IN SELECTED COMMODITY PRODUCING INDUSTRIES

(Canada, 1953)

Industry	% of all materials purchased[a]	% of salaries and wages	% of net value of production	% of gross value of production	Thousand B.t.u. per $ of sales
Alumina	5	52	10	3	78
Aluminum	24	84	27	13	209
Nickel—copper	15	46	10	6	95
Lead—Zinc	16	86	70	13	87
Magnesium	25	38	15	9	120
Primary steel	21	27	10	7	97
Cement	88	135	27	20	440
Clay products (brick etc.)	53	32	17	13	364
Acids, alkalies and salts	22	43	17	10	161
Caustc and chlorine (only)	37	60	20	13	165
Nitrogerious fertilizers	43	77	27	17	177
Newsprint	20	51	18	10	144
Sulphate Pulp	9	37	11	5	96
Dissolving pulp	22	51	30	13	323
Crude abrasives	18	38	17	9	86
Average					
(a) Primary manufacturing[b]	13	49	15	7	50—440
(b) Secondary manufacturing	3	6	3	1.5	20— 30
(c) Total manufacturing	4	11	5	2	37

[a]Includes fuel and electricity.
[b]Includes primary food processing.

3

RESOURCES, TECHNOLOGY AND THE FUTURE

As we have seen, energy consumption everywhere has been mounting, and mounting steadily. Meanwhile, the emphasis has been shifting progressively from the renewable to the more exhaustible forms of fuel and power. Shortages have already been encountered in some areas and production costs, particularly those of the solid fuels, have been rising. These tendencies have become a matter of increasing concern, especially in the older coal and oil using areas of the world.

New sources of energy will, eventually, be available to supplement those in widespread use today. These, we know, will call for the investment of a great deal of additional capital. There is no assurance, furthermore, that their introduction will effect substantial savings in other directions. These are among the reasons why the related questions of availability, substitution, and price are of such universal interest today.

A good deal has been written in recent years about the extent of the demand for energy. Despite the extent of this research, the various authorities still differ as to their estimates, not only of past levels of consumption but also in respect of present rates of increase. The United Nations, in their publication *World Energy Requirements in 1975 and 2000*[1], puts the historical rate of increase in the order of 3¼% per year. Putnam in *Energy in the Future*[2] estimates that over the past century demand has been rising at around 3% per annum, and Robinson and Daniel in the United Kingdom give a figure of around 2% in their latest paper *The World's Needs for a New Source of Energy*[3]. But, despite these

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[1]This document was released at the International Conference on the Peaceful Uses of Atomic Energy at Geneva in August, 1955.

[2]*Energy in the Future* by P. C. Putnam, Consultant to the U. S. Atomic Energy Commission,, D. Van Nostrand, Toronto, 1953.

[3]*The World's Needs for a New Source of Energy* was written by E. A. G. Robinson, Cambridge University, and G. H. Daniel, Ministry of Fuel and Power, for submission to the Geneva Conference on the Peaceful Uses of Atomic Energy, in August, 1955.

differences, they all agree on this: that future requirements are bound to be even greater than those of the past; that regional shortages are likely to become more, rather than less, acute; and that the price of energy to the consumer may not only level off but possibly follow a rising trend over the next 25 or 30 years.

Demand projections are almost as numerous as the historical studies. The more optimistic, from an energy supply point of view, anticipate a lessening in raw fuel requirements as economic conditions improve. The pessimists, on the contrary, remain convinced that the past trends are the best guide to the future. They say that energy consumption will go on increasing, year after year, and that by 1980 or thereabouts the world will be using up its fuel and power resources at three times its present rate.

Striking a norm between these various projections, we find that the world's energy requirements might go on increasing at a rate of around 3% per annum compounded. This is equivalent to a doubling demand every 25 years—something which, in view of today's high level of use, presumes considerable expansion on each and every front from exploration and development right through to distribution and consumption.

We have already raised the question "Where will all this energy come from?" Does the answer still lie with the mineral fuels or will new sources be drawn increasingly into the picture? Will these prospective shortages, if they occur at all, be worldwide? Or will they, instead, be confined to a few isolated areas on this continent and in Western Europe? The answers to these various questions have important implications for Canada and we will do well to study them.

Let us start first with an examination of the changing world supply picture so that later we will be able to interpret Canadian trends in a somewhat better perspective. Having done this, the role which the Canadian resources may be called upon to play, not only in meeting this country's own needs, but also regional requirements in the United States, may be more readily understood.

Taking the global approach first—a number of easily defined and significant trends are already apparent. As might be expected the non-commercial fuels, principally forest and farm wastes, have been declining in importance. They are of little significance in the more industrially advanced parts of the world. In North America and Europe, wood makes up between 5% and 10% of total energy consumption; in the U.S.S.R., possibly 20%. But in Africa, Asia and some South American countries, the non-commercial fuels still constitute more than 50% of all the energy consumed. There it is employed primarily for cooking and heating purposes.

The solid fuels, principally fuel wood, anthracite and the bituminous coals, while still out in front as the major source of world energy, are stead-

ily losing ground to oil, natural gas and hydro-electricity. The petroleum fuels together will pass coal sometime before 1960. Oil alone will probably head all other fuels by 1965. Past happenings are brought out even more clearly by the following table.

World Consumption of Primary Fuels
(1929, 1950, and 1953)

	Period	Coal	Oil	Gas	Water power	Other[a]
Percent of world	1929	60	10	3	4	23
production	1953	45	23	9	7	16
Percent annual	1929-50	0.5	4.7	6.3	3.3	.3
increase	1950-53	—	5.0	7.0	3.7	—

[a]Wood, peat and farm wastes.
Source: U.N. *World Energy Supplies in Selected Years 1929-50.* Statistical Papers Series J. No. 1, 1953.

Nowhere has the swing from solid to liquid fuels been more apparent over the past half century than in the international trade. Coal, which comprised as much as two-thirds of all the fuel traffic moving between countries as late as 1929, was down to less than one-third in 1950, oil having taken a commanding lead in this respect. One of the contributing factors has been the steady trend to oil bunkering and the growing popularity, especially since the late 1930's, of motorships. But of even greater importance has been the steady decline in the cost of moving oil by pipeline and by tanker to the major consuming areas of the world. This, together with its comparative abundance, its long-run decline in price relative to that of the solid fuels and its comparable or greater efficiency in use[4], have all contributed to its popularity among energy users everywhere.

By contrast, the distribution of natural gas and hydro-electric power has been landlocked. The organization of these industries, being more highly institutional in character, has also had a tendency to confine their use to their countries of origin. Only recently, with the advent of the long distance natural gas pipeline and the realization that considerable economies could be effected by further integration, internationally, of electric power systems, have these latter forms of energy begun to enter in any volume into the world's trade in energy.

At one time, Western Europe was the world's principal source of export energy—mainly coal—the United States following far behind. Now the United Kingdom, for one, has become a net importer of coal. The Western European economy, as a whole, is roughly in balance, although sizable

[4]Oil is made more efficient in uses involving internal combustion engines. It is about equal to coal and much better than wood in most stationary applications. The principal exception occurs in modern, high pressure boiler systems. There, as in the latest thermal power generating plants, coal may be several per cent more efficient in use than the liquid fuels.

shipments are, from time to time, being received both from the United States and from Iron Curtain countries, particularly Poland.

Instead of energy moving outward in the form of coal, the situation has now been substantially reversed. Oil is now being brought in, not only to Europe, but also to the United States and Canada from the Caribbean area and the Middle East. The rapid turnabout in the liquid fuel position of the United States has been a major development. From the position of being the world's principal exporter of crude oil and petroleum products in the 1930's, she is fast becoming the world's leading importer of crude oil and the heavier petroleum products.

Confronted with difficult physical conditions and a chronic shortage of mine labour, Western Europe will be hard pressed to maintain its present output of coal. Supplementary supplies will continue to be purchased from this side of the Atlantic. Yet, with shipping and handling charges accounting for a large proportion of the total, there will always be a disposition to avoid dollar outlays of this kind. The Communist countries being preoccupied with meeting their own energy needs, are not expected to assist this situation materially. Local supplies of natural gas are limited, and the majority of Western Europe's better water power sites will have been developed by 1970 or thereabouts. Nuclear energy, while it may begin to modify the demand for solid and other fuels in the generation of electricity within a decade, may not make a significant contribution in other directions much before 1980. These are among the reasons why the emphasis in the United Kingdom and on the continent is likely to shift more and more to oil and to liquefied petroleum gases, produced at relatively low cost and transported chiefly by pipeline and tanker from the Middle East. This oil and gas will be called upon increasingly to meet the energy needs associated with the further expansion of transportation, industry, and commerce in Western Europe.[5]

The second major supply difficulty centres around the liquid fuel resources in North America. It has been variously estimated, and with many qualifications, that the peak in petroleum production in the United States may be reached sometime during the next 20 or 30 years. Natural gas discoveries, also, are showing signs of lagging behind consumption. In the absence of imports, they, too, may be such as to set an upper limit on the construction of new transportation and distribution facilities—a phase of American economic activity which has achieved spectacular results in recent years. This is not to deny that vast quantities of crude oil and natural gas will be produced in the years ahead. But it is to suggest that, if those American authorities who have been responsible for the preparation of such reports as that issued by the President's Material Policy Commission in 1952 are anywhere near the mark, we must expect first a levelling

[5]Since 1945 the demand for energy in Europe has been rising at a 5% per annum rate; *i.e.* approximately doubling every 15 years.

off and then a gradual decline in the rates of oil and gas production in the United States well before the end of the century.

Should this take place, imports will be necessary on a large scale. Deliveries of oil and gas from western Canada will help to relieve the situation. But even if these expand considerably, the eastern seaboard states would still have to call upon Caribbean and Middle Eastern sources to meet a much larger proportion of their over-all requirements than they do at the present time. This, in turn, assumes the mobilization of an even larger fleet of ocean-going tankers. It also assumes that strategic and other considerations will not be allowed to interfere with the rationalization, on a truly commercial basis, of the world's trade in petroleum.

Under freer trading conditions, North Americans will be bidding, and bidding increasingly, against Western Europe for crude oil from the Middle East. On the other hand, should the present United States policy of restricting imports from outside the Western Hemisphere persist, demand on this continent will be focussed upon a relatively small and possibly diminishing resource base. Shortages may develop more rapidly and, being protected from world competition, production costs on this side of the Atlantic could rise more rapidly than would otherwise be the case.

The tendency, then, would be for this more expensive oil to be confined to its more essential uses. Research, meanwhile, would be directed more towards the production of liquid fuels from such alternative sources as the oil shales, bituminous sands and the various grades of coal which North America possesses in abundance. An examination of the present pattern of use suggests that of the many applications crude oil now serves, half could be supplied from these alternative sources. This is true, at least in so far as physical feasibility is concerned. However, this would probably result in higher prices to the consumer.

The gasoline, kerosene, and the lubricants for fuelling and otherwise servicing North America's vast fleet of motor vehicles, aircraft and other motive equipment will continue to be produced, in large measure, from crude oil found and produced in the conventional manner. Other demands, such as residual space heating and the fuelling of diesel engines, which provide a premium market for the middle distillate oils, may also have to be supplied in this manner. But the use of crude oil products for process heating and steam raising could well be curtailed in the interests of better conservation. At the present time, well over one-half of all the fuel oil being consumed on this continent is being burned up by heavy industry, boilers, and in the production of electric power—uses which, assuming some further increase in price, could equally be served through the use of coal or through the substitution of liquid products derived from oil shale, bitumen, or the destructive distillation of coal itself.

Already this up-grading of the freely occurring oils is taking place. Petroleum refinery equipment, techniques, and operating procedures are

continually being redesigned and reorganized with this end in view. As a consequence, the yield of residual oil has been falling steadily. More of the heavy ends are being converted by catalytic cracking and reforming into the lighter middle distillate and gasoline range. The economic incentive is already there. It has taken the form of higher prices; prices which the user can well afford to pay because of the higher over-all efficiency of the equipment which he can employ using these more highly processed fuels.

The incentive provided by higher prices is also leading to better conservation practices and recovery techniques. Less natural gas and fewer of the natural gas liquids are wasted in the production of crude oil. More oil is also being withdrawn from the ground. Yet even today considerably less than half of all the oil in place in the average reservoir is being brought to the surface. Careful investigation has shown that, depending upon the character of the host rocks, 70% or 80% may eventually be reclaimed. Thus with the more intensive use of such techniques as controlled fracturing, gas repressurization and artificial water drives, "recoverable" reserves might be as much as doubled without a single new barrel of oil being found.[6] Much of this additional oil, futhermore, may be produced with only a modest increase in cost.

Continual advances are also being made in respect to exploration and development. The turbodrill, in particular, offers economies which may offset increased costs of looking for oil in more remote areas and at greater depth. Proponents of the turbodrill claim penetration rates of four to five times faster than those of rotary drills and more effective utilization of drilling equipment and crews. Better geological information and technological advances in respect to such modern aids as the airborne magnetometer will have similar effects. These advances together with the development of still more efficient means of overland and water transportation will help to keep the price of oil more or less in line with that of most other commodities.

Natural gas, long a by-product of the search for crude oil, has only now really begun to come into its own. At one time it was burned wastefully to produce carbon black[7] or sold on long-term contracts to bulk industrial users. Now, however, it is diverted more and more into such higher price applications as space heating, cooking, the heat treatment of metals and the production of organic chemicals; or fields where quality, cleanliness and ease of control are of paramount concern. Such market factors, together

[6]The authors of the Paley Report thought it possible to increase the recovery of oil in many places from the current 40% to over 70% using various recovery techniques including water drive, expanding gas-cap drive and dissolved gas drives. This, they stated, could be accomplished with only a "modest" increase in cost.

[7]Carbon black can be made much more efficiently from residual oil. The use of natural gas for this purpose is therefore being discouraged in most producing areas in North America.

with the compulsion borne of the rapid growth of consumption relative to proven reserves in the United States, has helped to bring this about. Long-term contracts, written when a great deal of natural gas was still being flared in the fields and long-distance construction costs were but a fraction of what they are today, have had a delaying effect. Yet, with the incentive provided by new and higher priced markets and the concern reflected in government regulations, a steady upgrading is taking place.

In moving to market it has come into competition with oil, particularly the middle distillates. Off-season, and in areas where it is being introduced for the first time, it has had to vie for outlets with the heavier and lower priced petroleum products as well. In most places it has gone, it has displaced coal. It has hit coal hard in the retail market, where sales for space heating to residential and commercial customers have been particularly important. It has had an impact not only in secondary manufacturing, where energy in a concentrated gaseous form is particularly desirable, but also in heavy industry. In the case of sales to power producing utilities, the return per unit of volume is much lower, but such outlets have often been necessary for pipeline and distribution system load balancing purposes.

As time goes by, the volume of natural gas moving into these lower grade applications will probably decline relative to total consumption. Where geological conditions are suitable, underground storage will take the place of dumping sales of off-peak gas. Premium prices paid by those industries which can afford to pay more for gas as a fuel will reduce the necessity of always having to operate long distance pipelines at or near their maximum capacity. Less gas, as a result, will be sold in direct competition with residual oil and with coal, on a wholesale basis. This unique form of energy, in other words, will be used more selectively, and this, in turn, will help to reduce the drain on reserves which would otherwise take place in circumstances where price had less to do with the over-all allocation of the markets for fuels.

Many of the same uncertainties which apply to the long-run future of crude petroleum supplies on this continent also apply in respect to natural gas. Their prospects indeed are interrelated. At the present time about one-third of all the gas production comes from oil wells. Many straight gas discoveries, furthermore, have resulted from the search for oil. Obviously, as exploration and development on the latter account are intensified, more gas will become available.

But the search for natural gas, as such, will be stepped up. With rising prices, the results may be impressive. There is every bit as much energy in the ground in the form of natural gas as oil. Drilling to greater depths and in geologically favourable areas will tend to increase the gas-to-oil ratio. Eventually production and consumption of gas and oil will begin to approximate each other. Yet, because of oil's present marked lead, it

may be several decades before natural gas is making its full contribution in this respect.

As a major source of energy the natural gas liquids can be regarded as comparative newcomers. Yet they, too, offer a substantial reserve for the future. On the average, one barrel of natural gas liquids has been found for every six barrels of crude oil discovered on the North American Continent. Improved recovery procedures and methods of handling have steadily increased their usefulness. Their era of long-distance transmission by pipeline and by ocean-going tanker is only now commencing. Like natural gas, engineering and market developments may therefore see these resources being brought to bear on energy markets whose distance from the source of these liquid fuels formerly made their servicing appear inconceivable.

Shale oil will probably be the first of the more intractable petroleum resources to supplement the better known liquid fuels in use today. In volume they are tremendous. It has been estimated that the oil content of the oil shales located principally in Colorado, Wyoming and Utah are far in excess of currently proven crude oil reserves.[8] Also, recent experiments by the United States Bureau of Mines show that liquid fuels can even now be made from oil shale at a cost not far out of line with that involved in producing petroleum products in the conventional manner.[9]

Canadians naturally enough, are much more interested in the potentialities of the bituminous (tar) sands of northern Alberta. These, geologists frequently quantify as containing oil in amounts ranging from 50 billion to 250 billion barrels of possible reserves. The upper figure, incidentally, is greater than the world's already proven crude petroleum resources. Here again production cost data are available. Estimates issued by the Province of Alberta in 1950[10] indicated that, using already established methods of mining and processing, oil could be produced and delivered at a price within 20% of the crude oil currently being recovered by conventional methods in western Canada. More recent experiments suggest that, within the next decade, petroleum products may be recovered economically from the tar sands and transported by pipeline to markets in the Prairies, on the West Coast and in the vicinity of the Great Lakes.

Here, as in the case of the oil shales we are envisaging a large-scale mining-cum-manufacturing operation. New operating techniques must be

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[8]Reserves of shale oil amounting to more than 500 billion barrels were reported by the U.S. Bureau of Mines in their publication *Oil Shale—A Chapter from Mineral Facts and Figures* published early in 1956. Proven U.S. crude petroleum reserves, by contrast are in the order of 40 billion barrels.

[9]The Paley Report Vol. V, states on page 108 "synthetic gasoline from shale is estimated to cost up to 25 to 30% more than gasoline from present-day crudes, with opportunities for cutting costs further as technology advances".

[10]See *The Development of Alberta's Bituminous Sands* by S. M. Blair, issued by the Province of Alberta, December, 1950.

developed and vast amounts of capital invested in machinery and equipment. The highly localized and remote character of these deposits will also present problems of transportation and marketing. New pipeline systems will have to be laid and many of the advantages inherent in the marketing orientation of present-day refineries will have been lost. These considerations, together with the fact that continual improvements in mining and processing techniques will have to be made in order to keep abreast of the gradual decline in quality of the source material will tend to prevent such unconventional sources as the oil shale and tar sands from supplying the bulk of North America's energy needs.

Coal, because of its relative abundance, may also join the bituminous sands and oil shales as an important source of liquid fuel. Though the high volatile bituminous coals are most satisfactory, other grades can also be used for this purpose. Most petroleum products ranging from the heaviest to the lightest oils can be made from coal using several different processes, all of which will doubtless be improved by further investigation. Suitable cost data, however, are hard to come by. Such as are available suggest that until conversion efficiencies can be improved and the problem of by-product disposal overcome, coal will not present a major threat to the more conventional sources of petroleum products.[11]

Attempts at gasifying coal aimed at yielding a practical substitute for natural gas have been more successful. Experiments initiated in Germany in the interwar period and under active study in the United States promise to make this hope a reality. Employing oxygen, the price of which has declined considerably over the last 10 or 15 years, and working at high pressures a high heat content gas can now be produced. Most types of coals can be used for this purpose. Pulverized prior to treatment, using a fluidized bed technique, they can be converted entirely to the gaseous state. The problem of by-product and disposal, including even that of coke, is therefore overcome. If necessary, manufacturing operations of this kind can therefore turn out a product which, because of its comparatively high heat content, can stand long-distance transmission. Used primarily to supplement natural gas around 1965 or 1970, coal in this way may be used much more extensively toward the end of the 20 or 30-year period which we have under review.

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[11]Considerable research was carried out in the United States by the coal and oil industries during the period of 1947-50. These programmes were subsequently dropped because the production of gasoline from coal appeared to be too expensive relative to crude oil as a source. Similar researches were pursued by the U.S. Bureau of Mines. This was also curtailed in 1953. The results obtained by the industry and by the U.S. Bureau of Mines indicated that costs up to three times that presently encountered using crude oil might be involved in the large-scale production of gasoline from coal either by the hydrogenization (Bergius) or the gas synthesis (Fischer-Tropsh) processes.

Of the lot, water power is perhaps the most limited resource. Many of North America's lower cost and more favourably situated hydro sites have already been developed. Only in Canada and, to a lesser extent in the United States Pacific northwest, is this continent's remaining potential both large and economic. Also, since the demand for electricity is, if anything, tending to accelerate, it appears the majority of these resources will have been exploited by 1980 or thereabouts.

For this reason, and because the generation of electricity by burning coal at the pithead is not possible in many areas, some of the larger utilities have begun to invest heavily in nuclear energy. That there is adequate source material there can be little question. The energy content of the presently known uranium reserves is many times that of coal, oil and natural gas combined. Pilot reactor processes have already demonstrated the physical feasibility of burning nuclear fuels to produce first sensible heat and then electricity. The cost and particularly the timing as to when these conversion processes will become economic are, however, more open to question. Though information presently available on this subject has not yet been backed up by operating experience, it would appear that the first nuclear power plants might become commercially "competitive" in eight to ten years time. First employed in the high-cost fuel areas of the Continent which are also deficient in water power, they may, with improvements, find much wider application after 1970.

As a result of the progressive upgrading of oil and natural gas, the shortage of suitable hydro resources, and the comparatively slow buildup possible with nuclear energy, coal by 1980 might well be on its way to regaining its present relative position as a source of energy in North America. Not only will this be true of the more highly industrialized areas of the northeastern United States and Ontario but it may also be occurring in places where such coal as is available can be strip mined at relatively low cost and converted into gas or electricity nearby.

Of course, the sequence of events may be quite different from that which we have envisaged. Peak petroleum production, even on this continent, may not be reached until well after 1980—perhaps around the year 2000. Natural gas may still be an abundant resource relative to consumption half a century from now. The costs involved in producing petroleum products from oil and shale in the United States and from the bituminous sands in western Canada may have been reduced to the point where these resources have begun to make an appreciable contribution to our energy needs. And the difficulties involved in building and running not only nuclear power stations, but also nuclear fuel fired boilers, may have been exaggerated. Even solar energy, despite the fact that its use might be confined to the southern states, may also have begun to qualify as a commercial source of energy. These various resource qualifications together with a possible slowing down of the over-all demand for energy, could lead us to somewhat

different conclusions particularly in so far as the 20- to 30-year demand for coal is concerned.

Yet one thing, at least, seems certain: energy in its more desirable forms, such as hydro power and natural gas, will be used more selectively. Other sources, not the least of which is nuclear energy, will have to be applied to the lower priced, large volume applications which they are vacating. There can be no doubt that these supplementary sources of fuel and power will be available. But the real question is, "At what cost?" This can be answered only after making a more thorough examination of prospective developments in respect of the supply of and demand for energy in Canada, the United States and elsewhere.

4

A COMMENTARY ON PRICES

In circumstances where demand is pressing persistently on supply, price tends to rise. Usually it increases in real as well as current dollar terms. On the supply side, rising costs may also be a contributing force. More goods and services are employed in producing the commodity in question and its market price, reflecting these pressures, moves upward relative to that of other things.

This test can be applied to energy. Consumption over the past decade has been rising at an unprecedented rate. The search for additional resources, meanwhile, has been extended to new fuels and outward toward more distant sources of supply. Costs, as in the case of other commodities, have risen in current dollar terms. Yet energy price changes, when compared to the price changes which have taken place with respect to other goods and services have been less than is generally realized.

The situation varies, of course, from country to country and from region to region. In the more highly industrialized parts of the world real price has tended to rise. In others, and particularly in circumstances where indigenous sources of supply have recently been discovered, it has fallen in the relative sense. In Western Europe energy costs have generally tended to go up. This has been true particularly since 1939. The United States, though its energy price level is still far below that of most other countries, is faced with a similar situation. In Canada, on the other hand, the price of energy has tended to fall relative to that of other goods and services.

The improvement in the supply situation in Canada, as opposed to that in the United States, is illustrated by the following table. It shows the relative price of fuel energy declining in Canada and increasing in the United States over the past two decades.

Relative Price of Fuel Energy[a]
In Canada and the United States
(1925-55)

Country	1925-29	1930-34	1935-39	1940-44	1945-49	1950-54	1955
Canada	96	129	100	79	89	84	87
United States	95	95	100	96	108	112	113

[a]Price at source divided by wholesale price index for all commodities in index number form, 1935-39=100.

It is necessary to look beyond these composite price indices and examine the movements which have occurred with respect to individual fuels and electricity if one is to understand their true meaning. In the United States the inflationary trend in mineral fuel prices has been largely due to coal. As shown in the accompanying chart Relative Prices of Fuel and Power in Canada and the United States 1900-55, the real price of coal has been trending upward ever since World War I. The price of oil, meanwhile, has remained comparatively stable. Those of natural gas and electricity have actually declined relative to other goods and services. Were we to employ relative price as a guide, we would conclude that coal, alone among the mineral fuels, was in comparatively short supply. Despite the fact that North America's remaining resources of liquid fuels and water power are said to be limited, there is little evidence in past cost or price data to indicate that the United States is in danger of exhausting these desirable energy sources within a decade or two.

Canadian price data differ from those of the United States in several respects. Until recently the wholesale price of fuel in this country was much the higher. (See chart, Bulk Fuel Cost Areas—Canada-U.S.A.). Only in respect to water power has Canada enjoyed a long-term price advantage. Recently, however, the source prices of both oil and natural gas have fallen to a point where they were in line or somewhat below those prevailing in the United States. Only in the case of coal have prices at the mine remained substantially above those quoted in the United States. The over-all cost of energy in any one economy depends also upon the relative amounts of different fuels employed. Now, with the contribution of coal falling relative to that of the liquid fuels and water power, the average price paid for energy in this country is tending to move downward toward the North American average.

Trends in price at the source are one thing; price movements at the retail or consumer level may well be different. With the advent of the large, specialized collier, the oil tanker and the large diameter pipeline, the unit cost of transporting energy has fallen. The records of the United States Inter-State Commerce Commission applying to trunk oil line operations in the United States show that rates have declined by better than 50% since the late 1930's.[1] The construction of long distance natural gas lines and higher volttage power transmission systems have had similar effects. As a result price differentials in many consuming areas have been reduced; either that or energy deficient areas have been able to draw more economically on distant sources of supply.

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[1]The records for trunk lines of the United States Inter-State Commercial Commission show that when unit transportation charges are converted into constant money values they are seen to fall from approximately 60¢ per barrel per 1,000 miles in 1938 to approximately 24¢ per barrel per 1,000 miles in 1955.

Various Canadian retail price series confirm the view that the delivered cost of energy has either remained stable or tended to decline relative to the price of most other commodities. Manufacturing plants in this country currently pay about the same in real terms as they did in the late 1920's. Since 1939 the delivered cost of fuel and power (combined) has fallen to a level about 15% below that paid by most Canadian manufacturing concerns in the immediate prewar years.
(*i.e.* cents per million B.t.u. when related to the wholesale price index.)

Trend in Delivered Price of Energy to Manufacturing Plants[a]
(Canada 1933-53)

	1926 (est.)	1929 (est.)	1933	1937	1939	1944	1946	1948	1953
Cost in cents/ million B.t.u.	47	45	36	35	36	43	46	55	64
Wholesale price index 1935-39 =100	130	125	87	108	99	131	139	193	221
Real price[b]	37	36	41	32	36	33	33	28	29

[a]Such data as are available for the United States (1929-47) suggest that there has been little change in the real price of energy delivered to manufacturing plants in that country. In passing it is also interesting to note that the average price paid per million B.t.u. has ranged between 40% and 80% higher to Canadian as compared to American manufacturing plants.

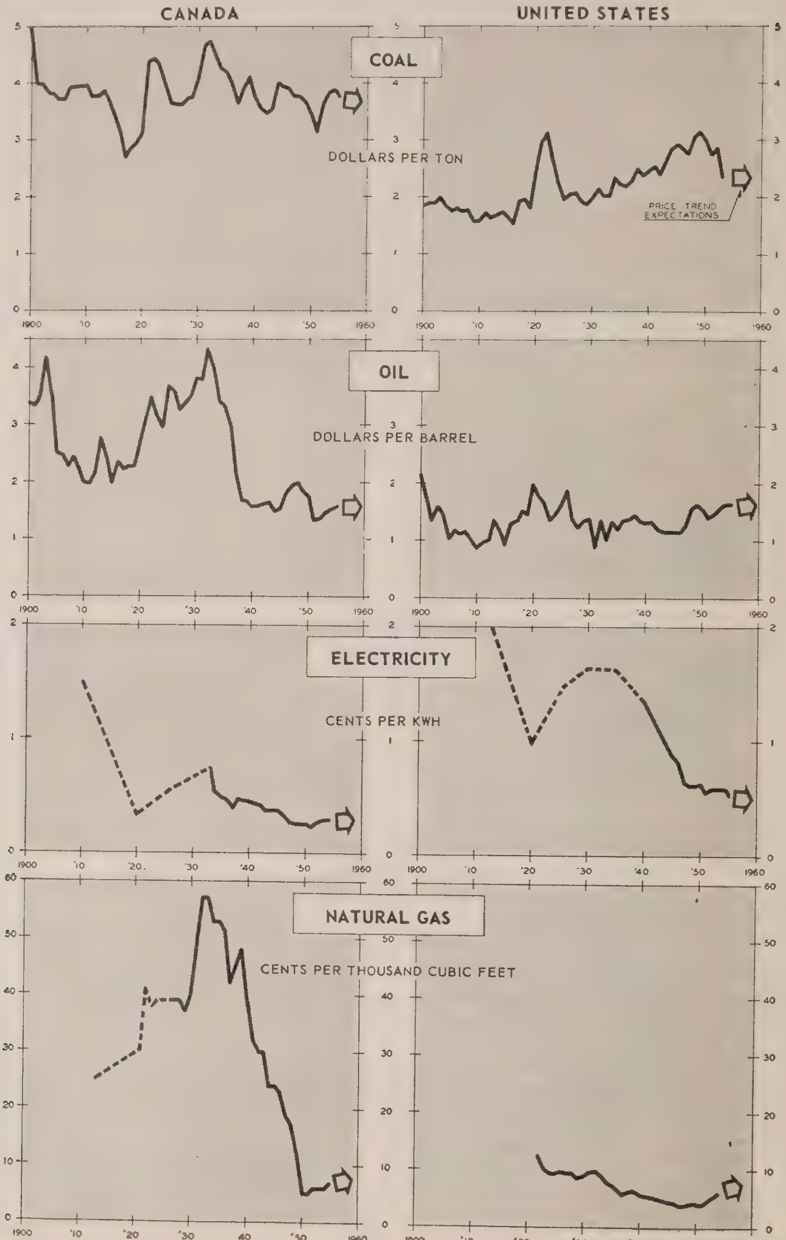
[b]Delivered cost of fuel and power at factory divided by wholesale price index for all commodities in index number form, 1935-39 = 100.

This highly generalized series results from the interplay of various forces. The fuel mix has been changing. Oil and electricity, (both of which are generally more expensive per B.t.u.) have been gaining on coal. This tends to give an upward bias to the later figures. Secondary has been growing relative to primary manufacturing in Canada. Because plants in the former category are generally smaller and use energy less intensively they usually pay more per B.t.u. for their fuel and power. During the past 20 to 30 years a number of pulp and paper mills and smelters and refineries have located and then expanded in remote areas of the country. This has also helped to inflate the average delivered price of energy to Canadian manufacturing establishments. Hence one can argue that the laid-down cost of energy has probably fallen farther than the above series would indicate.[2]

Wholesale prices reported by large energy users in a number of Canadian cities also tend to confirm the view that the delivered cost of energy has

[2]For further details see the table entitled Trends in the Delivered Price of Energy to Various Canadian Manufacturing Industries, Canada 1926-1953.

RELATIVE* PRICES OF FUEL AND POWER



* CURRENT PRICE AT THE MINE OR WELL DIVIDED BY THE WHOLESALE PRICE INDEX FOR ALL PRODUCTS 1926 = 100
ELECTRICITY PRICES ARE FOR "LARGE POWER" CATEGORY ONLY.

BULK FUEL COST AREAS – CANADA – U.S.A.
CENTS PER MILLION BTU DELIVERED

tended to decline over the past 20 to 30 years. The index published by the D.B.S. for all types of fuel and power (including fuelwood), while it appeared to rise sharply during the late 1920's and early 1930's, has since fallen by an even greater amount. The drop over the past 25 years has been in the order of 40% of the average wholesale price prevailing during the interval 1930-34.

The price paid by householders in Canada has roughly paralleled those prevailing in industry. While the national cost of living index (1935-39 = 100) rose from approximately 122 in 1929 to 187 in 1955 the component index for fuel and lighting increased from 113 to 152. The over-all index, in other words, has gone up by nearly 50%; that of energy used in households by something like 40%. It is also interesting to note in this connection that the real price paid by householders for coal has gone up by about 10% and that for fuel oil remained comparatively unchanged during the past quarter century. Meanwhile the cost of both electricity and natural gas to the average Canadian home owner has been cut to about half of the price level prevailing in the late 1920's.

As the foregoing data do not take into account such consumer benefits as result from the adoption of more efficient fuel burning or power using equipment, energy put to effective use is clearly becoming a less expensive commodity.

In the following chapter certain basic assumptions have been made as to the future course of prices. In the main they follow from the historical cost and price trends outlined here. For the record (and in the interests of clarity) the assumptions employed are listed here:

(1) that the real price of coal at the mine in the United States will tend to level off and in Canada show a modest decline over the next 20 to 30 years;

(2) that the price of crude oil at the field in the United States will begin to rise relative to other commodities in the 1960's, but will not be more than 20% above its present level in 1980. Meanwhile, the combined costs of exploration, development and production of oil in this country may remain unchanged;

(3) that the price of natural gas as reflected in new contracts at the field in Canada may approximately double and that the source in the United States may rise by about 50% in real terms over the next 25 years;

(4) that the delivered price of electricity will fall by a further 10% in the United States and rise by 10% to 20% in Canada over the next quarter century; and

(5) that the delivered price of fuel energy will rise by 10% to 20% in the United States and fall by a comparable amount in Canada during the 20- to 30-year period under review.

PART B

THE ENERGY-SUPPLYING INDUSTRIES

5

THE FUEL AND POWER INDUSTRIES IN PERSPECTIVE

A GREAT deal that is descriptive has alread ybeen written about Canada's individual fuel and power industries. Much less has been said, however, about their contribution, collectively and one as opposed to another, within the framework of the Canadian economy. Some discussion along these lines is essential if we are to obtain a better understanding of the role which coal, oil, natural gas, water power, nuclear energy, etc., are likely to play in respect to the nation's future development.

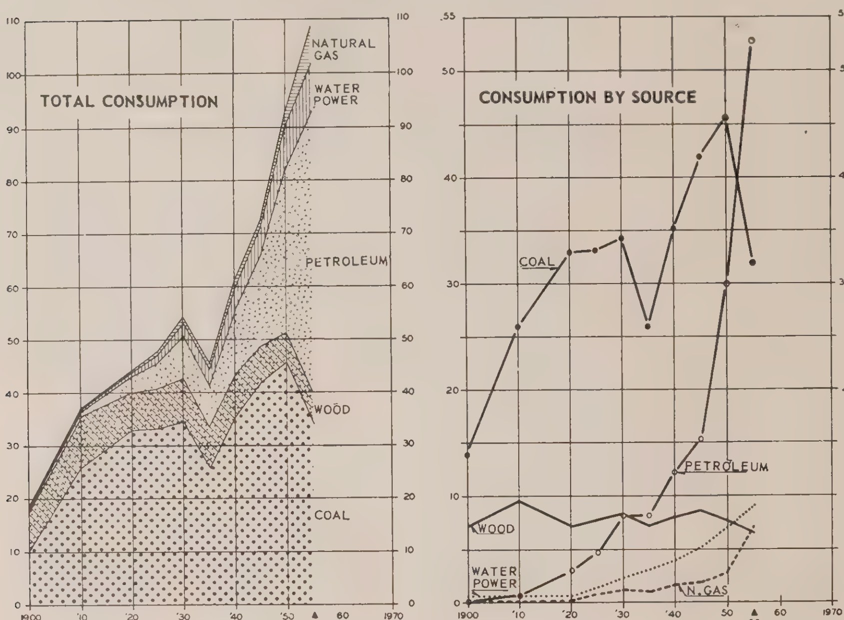
Until quite recently the solid fuels have been dominant. Coal and wood, together, supplied more than half the nation's primary energy requirements as late as 1950. Oil passed coal for the first time in 1952. Water power moved ahead of wood in 1951. Natural gas, though it shows considerable promise, is still in fifth place. That the Canadian economy, in 1955, was still heavily dependent upon the same forms of energy as have been in widespread use for more than a half century is apparent from the accompanying tables and charts.

Consumption in primary form is one thing. Effective utilization is often quite another. The real contribution made by hydro-electricity is much greater than any analysis of inputs will show. Losses in generation, transmission and distribution constitute a much smaller percentage of production than is the case with fuels. In total, they may amount to no more than 20%. The input-output relationships with respect to the fossil fuels would indicate a much lower level of efficiency. Depending upon application and the types of equipment employed, losses in their case may vary anywhere from 40% to as high as 95%. A tabulation of the latest (1953) data pertaining to consumption by source and effective utilization brings out these relationships quite clearly. (See Chart: Consumption of Energy in Canada 1900-1955.)

Canada — Energy Effectively Used — 1953
(in millions of tons of coal equivalent)

Commodity	Supply	Effective utilization	Losses	Losses as % of supply
Coal	38.5	14.	24.5	63
Oil	41	16.	25.	61
Water power	8	7.2	.8	10
Fuel wood	6	1.8	4.2	70
Natural gas	4.5	2.5	2.0	45
Total	98	41.5	56.5	57

CONSUMPTION OF ENERGY IN CANADA 1900–1955
IN MILLIONS OF SHORT TONS COAL EQUIVALENT

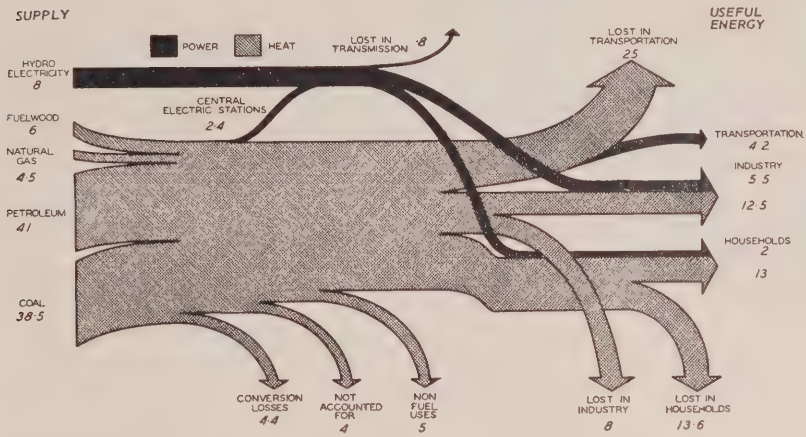


Of equal, if not greater, interest is the degree of dependence upon external sources of supply. Traditionally, this country has been an importer of fuel. As late as 1950, some 60% of all the energy in Canada had to be brought in from outside. Nearly two-thirds of the coal was mined in the United States. Three-quarters of the crude oil was produced in the mid-continent area of the United States, California, Venezuela and the Middle East. Refined petroleum products were imported to the extent of 20% of consumption. Only in respect to water power, fuelwood and natural gas could Canada be said to be substantially self-sufficient.

As a result of the discovery of oil in western Canada and the displacement of coal from a number of its old-time markets, the extent of this dependence upon foreign sources is changing. By 1960, Canadian-produced oil and

natural gas will be available to at least half of the nation's population. A surfeit of natural gas liquids in western Canada and the availability, after 1965, of nuclear energy will also serve to curtail imports. Yet—and this applies with some force to southern Ontario, Quebec and the Atlantic region—there will be a continuing need to import energy in both its raw and semi-processed forms. American coal will certainly be needed for the generation of thermal power in southern Ontario. Also, it will be purchased in some volume by heavy industry in the central provinces. Oil refineries in Quebec and the Atlantic region will, in large measure, continue to rely on imported crude. Petroleum products to the extent of 10% or 15% of Canadian consumption may also continue to be purchased abroad.

ORIGIN AND UTILIZATION OF CANADA'S ENERGY 1953
IN MILLIONS OF SHORT TONS COAL EQUIVALENT



Yet, on balance, and largely for geographical reasons, Canada may become a net exporter of energy. The nation's as yet undeveloped fuel resources, although confined largely to western Canada, are tremendous. In what follows, it is suggested that the nation's commercially recoverable crude oil reserves may ultimately approach 50 billion barrels; that those of natural gas may amount to several hundreds of trillions of cubic feet and that coal to the extent of 30 billion tons can be mined at or at about, present day costs.[1] Leaving out of account such potential resources (*i.e.*, resources which are not commercially recoverable using present day methods) as the Athabasca tar sands of northern Alberta[2] and much of the lignitic and sub-bituminous coal which underlies much of the western Prairies, these alone are sufficient to meet present Canadian needs for something like a thousand years. Even if the total demand for energy in this country should rise at a rate of some-

[1]In terms of coal equivalent 50 billion barrels of oil = 11 billion tons; 300 trillion cubic feet of gas = 11 billion tons coal equivalent.

[2]The tar sands, if taken as containing 300 billion barrels of oil, equal 66 billion tons coal equivalent.

thing like 5% compounded annually, they would be adequate to cover Canadian requirements for several centuries.

Only on the power side must qualifications be made. The majority of this country's larger and more accessible hydro-electric resources, though extensive, will have been largely developed by 1980. Certainly, the best sites will have been harnessed by then. Electricity from thermal sources may be more than competitive on the Prairies. Elsewhere, it is to nuclear energy that the rest of Canada must ultimately turn. Hence this novel and, to all intents and purposes, unlimited source may eventually be required to play a major role in the providing of electricity for residential, commercial and industrial purposes.

In general, supply is unlikely to be a matter of national concern; at least during the next quarter century. Rather, it is to the qualifying conditions of availabity that we must address ourselves. One is markets. Large volume outlets, in most cases, are a prior condition to efficient development. Another is a high prospective return on sales. Both of these conditions must be favorable before the capital required to finance, develop, and distribute this energy will be readily forthcoming. Fortunately for this country, the export possibilities with regard to oil, natural gas, and water power are such as to facilitate both the launching and, if necessary, the recapture of much of this capacity for Canada.

6

THE COAL INDUSTRY

Section I: Introduction

Coal, the fuel which sparked the Industrial Revolution, is at the crossroads. In many parts of the world, the day of the small, independent producer is coming to an end. Large mining corporations, tied contractually or corporately to other types of industrial activity and capable of planning their output for many years ahead, are taking their place. The number of retail outlets engaged exclusively in the marketing of coal are also on the decline. Larger tonnages are being sold to power generating utilities, metallurgical concerns and chemical manufacturing plants. A new industry is therefore emerging. Capable of raising large amounts of capital for forward development and at the same time geared to demands which are more predictable, more specific as to quality and less subject to displacement by other fuels, it is assuming a structure which is corporately and financially quite different from that which characterized coal production and marketing up to the outbreak of World War II.

The tempo with which these changes have been taking place has varied from one nation or region to the next. Many parts of the world possessing their own supplies of oil and natural gas now employ coal closer to the mine than formerly and mainly in the lower price categories of use. This is the case in the United States where the transportation and space heating markets have largely been taken over by the liquid fuels and electricity. They have been less evident in the United Kingdom and certain other countries in Western Europe where coal is the only indigenous energy resource. There, acceptance of the various grades of fuel oil has come more slowly. Vehicular transportation has long been predicated upon gasoline: but power, and to a lesser extent industrial production, is linked much more closely to the rate at which coal can be produced.

It is against a background of full employment that coal has been found most wanting. The creation of additional underground mining capacity

involves considerable forward planning; often years for its completion. Therefore, unless a goodly supply of coal can be won by strip-mining methods, supply responds more slowly to demand than is generally the case with oil and natural gas. Coal prices during periods of sustained economic expansion have also tended to rise relative to those of other goods and services. Under these circumstances, the other sources of energy have not only become more competitive in price but frequently have been the only ones available to ensure a steady measure of economic growth.

This has been the experience of most of the coal based economies in Western Europe since 1945. Similar conditions were encountered in the United States between 1940 and 1949 and in Canada as late as 1952. Many industrial consumers, wishing to ensure themselves of an adequate fuel supply and at the same time hoping to improve their bargaining position, have therefore been tempted to install dual-firing equipment so they could switch readily from coal to oil or from coal to natural gas at comparatively short notice.

While competition has become more intense, demands of a more persistent character also appear to be emerging. Various of the heavier industries have begun to search for and obtain reservations on deposits which can be mined cheaply and are, at the same time, not too far from the principal markets for their products. Many of the larger steel producers are blocking out large reserves of coal with good coking and other metallurgical properties. The aluminum industry has recently located much of its new smelting capacity in areas where electricity can be produced reasonably cheaply from coal by thermal means. Certain chemical companies, intrigued by the wealth of organic substances which can be made synthetically from coal, have also been buying up deposits where sub-bituminous and lignitic coals can be mined mechanically and at comparatively low unit cost.

All agree that the world's resources of crude petroleum and natural gas are limited by comparison. Another 50 or 100 years could see their exhaustion; an eventuality which would become much more imminent were the potential liquid fuel producing areas of Asia to be denied to the West for political reasons. In some parts of North America the situation is even more pressing. Here the ill effects of resource depletion might begin to put in their appearance before 1980. Many experts in the oil industry predict that the cost of finding crude petroleum may begin to mount relative to that of other goods and services in the 1960's or 1970's. Natural gas, though more abundant relative to demand, may also be more expensive to find and produce a quarter century from now. Nuclear energy, because its initial contribution may be confined to the production of electricity, offers but a partial escape from this dilemma. Coal, therefore, may regain some of its former importance both as a source of heat and as a chemical raw material. First through the medium of electricity and, later, as a source of synthetic liquid fuels and gases it may re-enter a number of industrial, commercial

and residential applications which it once supplied, though less conveniently, in solid form.

In recent years the pace of technological development has increased. A number of technical innovations have encouraged rather than detracted from the use of solid fuels. Special earth and rock moving equipment have been devised for coal and other types of mining. They have facilitated the removal of over-burden and therefore rendered economic the strip mining of coal seams of lesser thickness and at greater depth. Drag lines, large capacity power shovels and giant diesel powered, off-the-road trucks have also helped keep on-site labour costs at a minimum. Underground, the mechanization of cutting, handling and conveying coal has yielded similar though more often less spectacular results.

Improved methods of preparation have also increased the marketability of coal both to heavy industry and to the electric power producers. Improved collier loading and unloading facilities, and shipping designed and used specifically for the purpose are helping to reduce costs of movement. Overland conveyor belt and pipeline systems built to operate continuously and at or near full capacity may go even further in this direction. Yet even more important are developments at the user level. Due to improvements in consideration of efficiency, less wastage is being reported in industry and the heat rate of thermal power stations is continuing to rise. Meanwhile, user equipment, designed specifically for the purpose, has enabled the lower ranks of coal (including coal which was formerly abandoned as waste), to be burned, and burned economically.

Because of these developments, unit energy costs rather than such former considerations as to lump size and ash content are becoming the main determinants of use. More consumers are making their choice in terms of the delivered price of coal per B.t.u. They also require a degree of uniformity consistent with the specially designed equipment which they have ordered for their purpose. Beyond that they are indifferent as to whether the coal is anthracitic, bituminous or even lignitic in rank.

This comparative freedom of choice on the part of the user has important regional implications. Areas which were formerly at a disadvantage because they lacked deposits of coal of a given quality are now able to employ their lower rank and usually more accessible material to advantage. Western Canada, because it possesses extensive deposits of sub-bituminous and lignitic coals which can be strip mined mechanically and at comparatively low unit cost, is already benefiting from this broad trend in utilization.

There are exceptions of course. Good quality coking coal is becoming scarce. This is true not only in Western Europe but also in those producing areas of the eastern United States from which most of Canada's steel mills have been drawing their supplies. A concerted attempt is therefore being made to press some of the poorer quality but more widely occurring coals

into use. Blending is common practice and other blast furnace feeds are being adapted to the more extensive use of run-of-mine qualities. These practices, though their penalty can be minimized, are leading inevitably to higher energy costs. Fortunate are such areas as western Alberta and south-eastern British Columbia which possess extensive deposits of an increasingly valuable resource of this kind.

But now we are beginning to discuss coals which are anything but wide-spread in their occurrence and which, as the pace of industrialization increases, are likely to earn an even better return in the markets of the world. They are materials which, by themselves, are insufficient to attract new industries. Other natural resources, not the least of which are coals of other ranks and degrees of accessibility, must also be present. With this in mind, we will do well to discuss the general location and quality of the Canadian, North American and world solid fuel resources before going more deeply into an assessment of the longer term demand for coal as a source of energy in the Canadian economy.

Section II: Canada's Coal Resources in Perspective

It is useful, at the outset, to obtain some understanding of the extent and location of the nation's coal resources. Having done this, and having assessed them in relation to those elsewhere, the reader is in a better position to evaluate two things: namely, why coal, like nuclear energy, is one of the great reserves for the future; and why, in the struggle for markets which has been going on over the past half century, Canada's coal mining industry—and particularly the underground mines—has encountered serious competition not only from oil and natural gas but also from imported coal.

Reserve statistics can be misleading, especially where international comparisons are involved. Definitions as to quality often differ from one country to the next. So does the concept of what is economically recoverable coal. Downward revisions have often been dictated by experience; particularly experience which shows that, through the workings of the market, coal which at one time could be mined and sold at a profit is no longer commercially attractive to produce.

Canada's case is a good example. This country's reserves, which were placed over 1,200 billion tons in 1913, are now thought by our federal and provincial geologists to be in the vicinity of 94 billion tons. This 90% reduction would take a good deal of explaining were it not for the fact that the former estimate was a first approximation of the total amount of coal believed to occur in the ground within the very broad limits set for the depth and thickness of the seam. The latter estimate, obtained by using much narrower limits of seam depth and thickness, is more realistic and more nearly represents the amount of coal that could be mined profitably using present-day techniques.

Several qualifications are necessary before our coal reserves can be compared with those of other fossil fuels. Of the total reserve of 94 billion tons it is estimated that about two-thirds, classified as probable, can reasonably be expected to exist as mineable coal. The remaining one-third, classified as possible, has a lesser degree of certainty of existing as mineable coal and for various reasons its recovery is more problematical. Both the probable and possible reserves are further reduced when it is realized that because of pillars that must be left, and because of other losses in the mining process, not all coal in the ground can be made available above ground as a marketable fuel. Thus the recoverable-probable reserves are estimated to be about 30 billion tons[1]

Estimating difficulties notwithstanding, it appears that Canada possesses a relatively small, though still significant, proportion of the world's coal resources. The latest available publication of the United States Geological Survey indicates that they amount to approximately 2% of that reported by all countries taken together.[2] In this respect Canada is overshadowed by the United States, in that the United States possesses something like 36% of the earth's total recoverable resources. Neither is it in the same category as the U.S.S.R. with 24% or China with an estimated 20%. This country's reserves are more comparable with those of the larger Western European producers. Compared to Canada's 94 billion tons a recent report issued by the Geological Liaison Office in London[3] shows the United Kingdom to possess about 150 billion tons of reserves. Poland is known to have about 80 billion tons. Australia, which is much more dependent upon coal production than Canada, has estimated resources totalling 45 billion tons.

In respect to quality, a somewhat different picture emerges. The geologists tell us that, as far as the coals of medium and lower rank are concerned, the scales are tipped heavily in favour of North America. They also say that more than half of the world's known bituminous coal deposits are in the United States and Canada. The Communist countries of Eastern Europe and Asia, on the other hand, can boast of two-thirds or more of the harder coals principally anthracite. At one time this would have been a disturbing admission. But now with heavy industry, and particularly the electric power utilities, willing to take anything from the brown earth-like lignites through to the harder and more combustible bituminous grades, the situation appears to be more reassuring.

Canada, with its reserves of bituminous and lignitic coals, though little anthracite, is favoured by this turn in events. It is fortunate in another respect as well. Among the bituminous coals, those with good coking quali-

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[1]At the current rate of mine output this would last the industry nearly 2,000 years.

[2]See *Coal Resources of the United States*, U.S. Geological Survey Circular 293, October, 1953.

[3]See *Coal Resources of the British Commonwealth* issued by the Geological Liaison Office, London, 1956.

ties are increasingly in demand. Other things being equal, it is to them that many of the world's metallurgical industries must go in search of raw material. Historically they have become a focal point for the production of primary iron and steel and, through steel, a host of other metal-producing and metal-using industries. Western Canada, in contrast to many parts of the United States, is fortunate in having a goodly supply of these premium quality coals in sight. As in the case with many of the nation's other resources, however, geographic as well as market considerations will continue to exert a moderating influence upon their rate of exploitation.

First as to the nature of this country's deposits. Canada's coal reserves are predominantly bituminous in rank. Some 15% is of low volatile bituminous rank; 31% is of medium volatile bituminous rank; 17% is of high volatile bituminous rank; 9% is sub-bituminous in character and 28% is classified as lignitic. The medium volatile group is of greatest interest for it is here that the best coking coals are likely to be found. Only occasional deposits of anthracite are known to exist and these have been found in the more mountainous country of British Columbia and Alberta.

In volume terms about 95% of the nation's coal is to be found west of Winnipeg. Much of it occurs in Alberta, although both British Columbia and Saskatchewan can also boast of substantial reserves. A glance at the accompanying map will show that they underlie much of the Central Plains and extend beyond the foothills westward well into the Rocky Mountains. Throughout the Western Cordillera frequent occurrences have also been reported. Over this vast area, the character of the deposits varies considerably with coals of the highest rank generally being found in the more highly faulted and disturbed sedimentary strata which characterize the more mountainous country to the west. There, geological conditions have also favoured over great periods of time the formation of medium and low volatile bituminous coals. Proceeding eastward into country in which past conditions of nature have been less arduous, one encounters the high volatile bituminous coals of the foothills, then the extensive flat-lying deposits of sub-bituminous coal which are found at moderate depths throughout much of central and southern Alberta. Finally, there is the lignitic coal of southern Saskatchewan. Also lying close to the surface, it is being mined in increasing amounts for power production and other industrial purposes.

The mountain-building movements of past geological time, while they have helped to raise the rank of the coal, have also tended to increase the difficulties encountered in its recovery. On the one hand they have brought to the surface deposits that would otherwise have been under too great a cover. Seams have even been exposed, which, together with considerable thickening, has made them suitable for recovery by low-cost strip mining methods. Meanwhile, the attitude and waste content of other seams have become such as to present offsetting mining and marketing problems. These may be steeply inclined; or the seams may be cut off or severely thinned

by faults and folds. At the same time crushing may have made the coal unworkable or have resulted in a surplus of fines, off-grade or otherwise difficult to handle material in amounts over and above that which could be sold to large manufacturing plants and power utilities within easy distance of the mines themselves.

Mining problems, such as those referred to above, are not generally encountered in the Plains coalfields where the seams are frequently horizontal and more uniform in thickness. There it is possible to win much of the coal by stripping methods in which large power shovels and draglines remove 20 to 50 feet of overburden to expose the raw product. It is under conditions such as these, where extensive mechanization is possible, that coal mining has continued to flourish despite mounting competition from nearby sources of fuel oil and natural gas.

The coal reserves of eastern Canada amount to less than 4% of the nation's economically recoverable resources. These reserves are located, for the most part, in four coalfields: the Sydney coalfield on Cape Breton Island, (the most important field in the Maritimes); the Cumberland coalfield and the Pictou coalfield on the mainland of Nova Scotia; and the Minto coalfield in New Brunswick. The remainder are small and widely scattered. The coal known to exist in the Atlantic Provinces is bituminous in rank but there is considerable variation in its quality. Some of it exhibits good coking qualities but because of its high sulphur content its suitability for metallurgical purposes is reduced.

In Nova Scotia, all of the coal must be obtained by underground mining methods. There all of the more readily accessible material has been recovered. In order to reach what remains, the mines must be extended downward and outward. Where this also involves submarine workings, additional complications arise. Usually such mining and sub-surface transporation costs as are encountered tend to place the coal produced in eastern Canada at a disadvantage when competing with imported oil and the more cheaply mined coal from the eastern United States.

In New Brunswick all production, about 80% of which comes from strip mines, is obtained from a single thin seam in the Minto coalfield. This material has a high ash and sulphur content, which prohibits its use for coking purposes. It does, however, find a market in industry and in the generation of electric power by thermal means. About three-quarters of the province's annual production is being used for this latter purpose. At its current level of output the remaining life of the Minto coalfield is estimated to be about 75 years.[4]

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[4]By contrast, the Sydney coalfield in Nova Scotia has a remaining life, at present rates of production and percentage recovery, of about 200 years; that of the Springhill and Joggins areas, also in Nova Scotia, of about 100 years.

No discussion of our coal reserves would be complete without some reference to the location, quality and extent of the coal reserves of the United States. As will be seen from the accompanying map, the coal deposits of the United States are widely distributed, and large areas of coal lands are present in or near all parts of the country except the Pacific coast region. These deposits include a variety of coals ranging from anthracite to lignite. The area east of the Mississippi River contains 40% of the total reserves, most of it being of the higher rank bituminous coal with some anthracite deposits concentrated mainly in eastern Pennsylvania. This same area accounts for over 90% of the United States production with most coming from the Appalachian Basin which extends from Ohio and Pennsylvania to northern Tennessee. Extensive deposits of bituminous coal have been outlined in Iowa, Illinois, and a number of the other midwestern and south-central states. It is this coal, select pockets of which lend themselves readily to coking and other industrial purposes, which helped the United States supplant Great Britain as the world's leading industrial power in the 1890's. It is this coal which provided the foundation upon which the dynamic economy of the early 20th century America was built. And it is the same fuel which, for over 50 years, has been flowing in increasing volume into the homes, stores, factories and power plants of Southern Ontario and Quebec.

As one proceeds westward, the United States appears to be in a less favourable position. Granted the reserves are even larger in tonnage terms; but they are, at the same time, lower in rank. There the lignitic and sub-bituminous coals are much more in evidence. Also, it usually happens that the better grades are to be found as one proceeds northward into Canada. This is true particularly of the coking varieties and of the sub-bituminous coal in mineable quantities which are located within several hundred miles of the Pacific Ocean.

These qualitative considerations, together with the fact that western Canada's extensive coal resources are favourably located with regard to future west coast trade, have interesting implications. Demand for metallurgical and other industrial purposes will eventually increase both in the United States Pacific Northwest and in California. A goodly proportion of these needs can best be met from Alberta and B.C. sources. This being the case, we may one day witness a reversal in the preponderance of the north-south trade in coal which has grown up between Canada and the United States over the past 75 years.

Thus, as with oil and natural gas, the geographical distribution of reserves may tend to move in Canada's favour as the centre of gravity of North America's population, commerce and industry, moves westward across the continent. Imports in the east may eventually be offset by exports in the west—an exchange of coal which, if it materializes, will redound to the greater advantage of both countries.


MAP SHOWING
COAL FIELDS
IN
CANADA AND UNITED STATES
SCALE OF MILES
Prepared by B.R. MacKay, Geological Survey, 1946
LEGEND
Anthracitic (anthracite and semi-anthracite)
Low volatile bituminous
Medium volatile and high volatile bituminous
Sub-bituminous
Lignite

Table 9

COAL RESERVES BY PROVINCES

(millions of short tons)

Province	Mineable Probable	Mineable Possible	Mineable Total	Recoverable Probable	Recoverable Possible	Recoverable Total	Total by %
Nova Scotia	1,797	1,190	2,987	899	595	1,494	3.2
New Brunswick	84	—	84	51	—	51	0.1
Ontario	100	50	150	50	25	75	0.2
Manitoba	34	67	101	17	34	51	0.1
Saskatchewan	13,127	11,004	24,131	6,563	5,502	12.065	25.5
Alberta	34,438	13,437	47,875	17,219	6,718	23,937	50.7
British Columbia	10,937	6,388	17,325	5,468	3,194	8,662	18.3
Yukon	416	1,432	1,848	208	716	924	1.9
Canada total	60,933	33,568	94,501	30,475	16,784	47,259	100.0

SOURCE: *Geological Survey of Canada,* March, 1956.

Definition of Terms

In the foregoing estimates not all coal in the ground is considered to be a reserve; only that which occurs within certain well-defined limits.

Mineable Coal

This is coal that is considered to exist in mineable thicknesses within a specified distance from the surface. These thicknesses are, in turn dependent upon such factors as the quality of the coal, the price that it can command in the market, mining methods, and availability of transportation. Since these factors vary from one locality to another, each coalfield has to be considered by itself, recent experience being taken as the principal criterion of mineability.

For Nova Scotia the estimate includes coal of a minimum thickness of three feet with not more than 4,000 feet of cover, (except for the Joggins coalfield where seams of a minimum thickness of two feet are included, and for the Springhill coalfield where one seam is included to a depth of 4,500 feet). For New Brunswick, seams averaging not less than 18 inches to a maximum depth of 100 feet are included. The estimates for Ontario, Manitoba and Saskatchewan include seams not less than three feet thick to a maximum depth of 500 feet.

Alberta sub-bituminous coals are estimated on the basis of seams three feet or more in thickness with not more than 1,000 feet of cover. The estimates of Alberta and British Columbia bituminous coals include seams not less than three feet in thickness with a maximum depth of cover of 2,500 feet. The reserves of British Columbia lignitic and sub-bituminous coals, and all coal in the Yukon are on the basis of seams not less than three feet thick with a maximum depth of cover of 1,000 feet.

Recoverable Coal

This is the amount of mineable coal that will likely be brought to surface. In few operations is it usual to recover 80% to 90% of the coal in the seam. In some instances it is as low as 20% of the mineable coal. In respect to Canada as a whole the extent of recovery averages about 50% and, therefore, the recoverable coal is assumed to be 50% of the mineable coal.

Probable Coal

This includes coal which by direct mining experience and by drilling, continuity to existing workings and areas drilled, or extensive geological data, can be reasonably expected to exist.

Possible Coal

This is coal (in addition to the probable coal) knowledge of which is based on limited geological data. Its recovery, furthermore, is problematical due to inferior quality or relative inaccessibility, or both.

Section III: Background and Current Structure of the Coal Mining Industry

Coal mining in Canada, as we know it today, is more than a century old. While frequent references are found in the log books of the early explorers, traders and fighting ships, the recovery of coal in the Maritimes had previously been a gathering operation. Lumps of coal were picked up along the shore or cut away from outcrops a short distance inland as and when the occasion required. In those days, coal still had to come into its own as a source of heat and power. Also, mining was initially prohibited by law. Thus the edicts passed by the central government in London for a time served to protect the coal mining industry in the old country from competition overseas.

The advent of the steam engine, and particularly the steamship and the steam locomotive, provided the first real incentive to production. It was largely responsible for the growth of the coal mining industry in Nova Scotia after 1830 and for the opening up of the first Alberta deposits in the 1880's. The initial efforts at mining on Vancouver Island similarly were aimed at the production of steam coal. There as in the Maritimes, export opportunities provided the necessary impetus, and operations got under way as early as 1850.

The fate of Canada's early export trade was bound up with the changing regional structure and growing competitive strength of the other North American producers. For more than a quarter century after 1855, Nova Scotia coal was sold down the east coast of the United States. Free entry resulted in increased shipments which, by 1865, accounted for more

than two-thirds of the total output of these eastern Canadian mines.[5] Abrogation of the Reciprocity Treaty between Canada and the United States in 1866 marked a turning point however. Thereafter, and influenced by increasing competition from the richer and more conveniently located coal-fields of the Appalachian Region, these exports began to fall off. High capacity coal-carrying railroads subsequently laid between the West Virginia fields and the Atlantic seaboard allowed these U.S. sources to capture and hold export markets which had been served for a time from Nova Scotia.

Coal movements southward from British Columbia, while more persistent, were finally arrested and then extinguished for other reasons. Heavy oil, originating in California, soon captured most of the railway and industrial markets along the west coast after it was discovered in 1910. Moving northward by tanker, it also took over much of the ships' bunkering trade—a revolution which was assisted materially by the virtual conversion of the world's shipping fleet to oil in the late 1930's and 1940's. Rising costs of production and a paucity of new deposits also contributed to the closing down, after World War II, of most of the mines on Vancouver Island. Over the past 25 years wood wastes like sawdust and later oil have dominated fuel production of the west coast.

Thus sales outlets internal to Canada became of increasing importance. Complementing the railway building boom, sales to iron foundries, steel mills and the first sizable machinery and equipment manufacturing plants also helped to expand output. Artificial gas production for street lighting gave an added boost to coal consumption after 1890. The new pulp and paper mills of the 1920's and the metal smelters and refineries of the 1930's also added to coal's opportunities at home. Residential and commercial space heating employed less wood and more domestically produced coal year after year until the late 1940's. Thus, with the railways leading the way, mounting Canadian requirements served to support an industry which, from its very beginnings, was faced with competition from external and internal sources of supply.

In the years immediately after Confederation, Nova Scotia coal began to move in increasing volume westward into Quebec and Eastern Ontario. A 50¢ a ton duty imposed in 1879 on imported coal helped. Yet, carried chiefly by water in the months when the St. Lawrence River was open to navigation, this business suffered both from its seasonal character and from persistent offerings from overseas. Timber ships returning from the United Kingdom with coal as ballast gave the latter a strong competitive advantage in the more lucrative space heating and industrial markets of Central Canada. Yet, this interregional trade grew and, by 1914, some 2,000,000 tons of

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[5]Exports in 1865 from Nova Scotia to the United States amounted to some 640,000 tons. Ten years later they had fallen to 90,000 tons following the imposition of a $1.25 per ton tariff.

Nova Scotia coal were being shipped annually up-river past Quebec City to Three Rivers and Montreal. War, after a comparatively few months, brought this hard-won business grinding to a halt. The diversion elsewhere of water transport under military priorities and, later, the submarine menace thus dealt a heavy blow to this struggling industry. Whereas more than one-third of Nova Scotia's total coal output had been shipped to markets elsewhere in Canada a few years previously, sales outside the province had fallen to minor proportions by 1918.

The industry's recovery in the early 1920's was assisted by strikes in the United States. Maritime production was needed in applications which otherwise might have resisted a return to Canadian coal. Also, as improved techniques of combustion were developed, a number of the newer and larger fuel using industries in central Canada were able to consume greater quantities of fine coal in the form of slack. This was indeed helpful to the industry in that it was thereby able to expand its sales of material which was not up to the standard of the premium grade screened coals demanded by the railways and by residential, commercial and small-to-medium industrial users located within the effective orbit of Maritime mining operations.

After 1928, assistance in the form of transportation subventions also began to be effective. This help from the federal government, together with continuing tariff protection and a well-planned sales campaign subsequently won further markets in the central provinces. This happened despite the Great Depression. Indeed, by 1936, as much as three million tons of Nova Scotia coal were being shipped up the St. Lawrence; one million tons of this was moving on past Montreal into Ontario.

World War II brought with it a repetition of the events which had beleaguered the industry some 30 years earlier. War demands for Sydney steel and for bunkering reduced the tonnages available for the St. Lawrence movement. Then, early in 1942, the submarines struck once more. The collier fleet, already partly requisitioned for other purposes, was virtually destroyed by torpedoing. From then on, such movements of Maritime coal as did take place to the central provinces became dependent upon and were seriously limited by railway and ferry connections. The mines, now with high inventories, soon went on short time. More of the younger and more active miners were recruited into the armed forces. Many never returned to their former occupation.

As was the case after World War I, a period of marketing difficulties and reorganization followed the end of hostilities. This time they have, if anything, been prolonged. Adequate shipping has continued to be in short supply. Water transport costs have therefore continued to be heavy. Having deteriorated under the stress of war, the physical conditions of the mines themselves have required a great deal of re-planning and re-equipment. The more modern types of machinery used elsewhere have rarely been found

suitable. Special measures have therefore had to be taken. Slowly labour productivity has crept back to the levels attained in the interwar period. Only during the last 12 to 18 months have there been signs that the long-run disabilities of the region are being overcome. Output per man-day is again edging upward. As a result, pithead costs are beginning to subside from their all-time high reached in 1953.

Out west, wartime conditions had a different effect. Shortages of coal in the United States during and immediately after World War I forced consumers as far east as Winnipeg to use Alberta coal for the first time. Once captured many of these outlets were retained. Transportation subsidies in the 1930's also helped to reinforce this trend. As a result British Columbia and Alberta coal began to be used more extensively in northern Ontario. Sporadic shipments even found their way to Sudbury and Toronto. Conditions since the early '40's have been less favourable. During World War II the shortage of railway cars dictated that they be used elsewhere than on long hauls of this kind. United States coal was therefore brought in over much shorter distances to serve industry and other consumers in Ontario. During the last decade many of these markets have continued to rely on imports. Users in central Canada, having become accustomed to regular deliveries and high standards of quality, have been loath to convert to the more expensive western Canadian products. Thus United States coal has improved its position both in heavy industry and in respect to the production of thermal power in the more heavily populated areas of Ontario south and east of Sudbury.

The plight of Canada's coal mining industry has not gone unheeded. Throughout much of its history, it has enjoyed a measure of protection from shipments from foreign sources. Import tariffs were invoked as early as 1879. Averaging out at around 50¢ a ton, they were designed initially to protect operations in Nova Scotia. With some moderate changes, they have been retained in order to help the mining industry at both ends of the country meet competition from United States coal in Quebec, Ontario and Manitoba. Freight subventions and export subsidies were also introduced during the late 1920's to keep the existing mines operating at or close to capacity. Applied uniformly across the country, they have helped to move Maritime and Alberta coal into central Canada and some Nova Scotia production to be sold overseas.

Despite this assistance, imports have, over the long run, grown relative to Canadian production. One of the causes has been the progressive concentration of industry and commerce in the central provinces. The centre of gravity of the domestic energy market has, in other words, been shifting gradually away from the Canadian mines. This has worked to the advantage of American producers; the majority of whom are more favourably situated in this regard. Another cause has been the relative improvement in productivity attained by the American mines. Always higher than the

Canadian average (see chart: Bituminous and Lignite Coal Canada-U.S. Comparisons), they have been gaining relative to the Canadian pits ever since the 1930's. Mine price discrepancies are also substantially greater than they were 20 or 30 years ago. Finally, there has been the incursion of oil. Moving from or past the Canadian sources of coal, it has benefited from more efficient pipeline and tanker movements. All of these factors, together with continuity of supply in wartime, have therefore worked toward a reduction in Canada's dependence upon internal sources of supply.

With the cost of coal at the mine in Canada tending to average out at a level appreciably above that in the United States and a lack of shipping together with rising rail freight rates presenting an even greater handicap, increased subsidies have had to be forthcoming if the industry was to regain some of its former outlets in Quebec and Ontario. This, in fact, is what has happened. Following the principle of helping Canadian coal to meet the laid-down price of imported coal at a number of the central points, federal expenditures on this account have risen considerably. In the vicinity of \$500 thousand in the late 1920's, they have since been stepped up to a figure in excess of \$10 million annually. Subvention payments in respect to Nova Scotia coal which amounted to 80¢ a ton in 1950 have now increased to approximately \$3.15. Total payments on this account in 1955 were in excess of \$8 million. The remaining moneys have largely been paid out in the form of assistance to the western Canadian coal operators. Thus, for the fiscal year 1954-55, the Dominion Board reports that Saskatchewan coal was assisted to the extent of 86¢ per ton; that of Alberta and British Columbia to the equivalent of \$2.79 a ton. Currently, such exports as move out of west coast ports receive a subsidy equivalent to 75c a ton. Meanwhile shipments from Nova Scotia overseas to the United Kingdom, the Low Countries and Germany are being aided to the extent of approximately \$2 a ton.

Over the years the structure of Canada's trade in coal has changed, sometimes in one direction, sometimes in another. Up until about 1910, domestic output continued to run well ahead of imports. But during World War I, and to an even greater extent during World War II much greater dependence had to be placed upon supplies from the United States. This recent shift in favour of foreign sources of supply is illustrated by the following table.

	1900	1925	1935	1940	1945	1950	1955
Imports as a % of domestic supply	43.0	57.0	48.5	52.6	64.0	61.3	58.4

Canadian production, meanwhile, has shown a moderate upward trend being interrupted only three times—during the 1914-18 war, in the mid-twenties and during the depression of the 1930's. By 1939 the industry had largely recovered from its latest setback and output reached new all-time peaks during World War II. The entire growth over this period, it should be noted, came from greater output on the Prairies and along the

BITUMINOUS AND LIGNITE COAL, CANADA–U.S. COMPARISONS

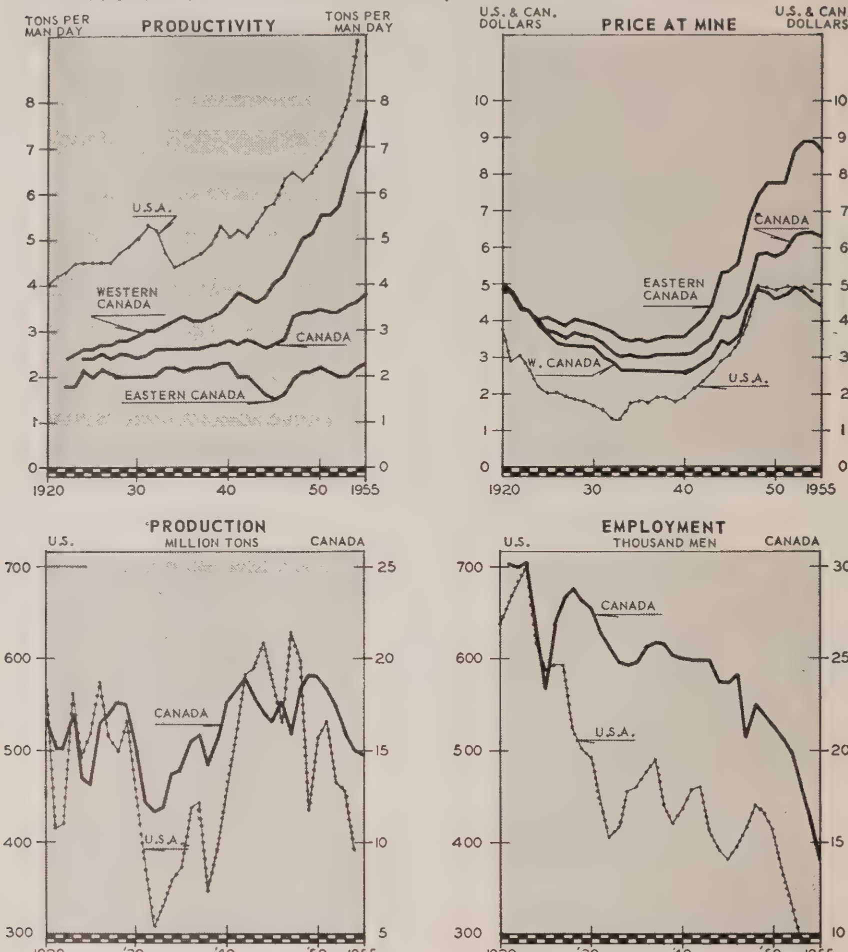

Table 10

CANADIAN COAL MINES OPERATING COSTS AND REVENUES PER NET TON OF MARKETABLE COAL PRODUCED

(1955)

	Nova Scotia		New Brunswick		Saskatchewan		Alberta (Prairie)		Alberta (Foothills)		Alberta (Mountain)		British Columbia and Yukon	
	Cost %	$	Cost %	$	Cost %	$	Cost %	$	Cost %	$	Cost %	$	Cost %	$
Operating costs														
Labour	47.9	4.77	47.8	3.63	24.8	.42	49.0	2.31	54.2	3.75	43.7	2.86	50.5	3.33
Welfare fund	1.4	.15	.2	.02	1.1	.02	2.3	.11	3.5	.24	3.2	.21	2.9	.19
Vacation pay	3.5	.35	.9	.07	1.5	.02	1.6	.08	2.2	.15	1.7	.11	2.1	.13
Workmen's compensation	2.1	.21	1.3	.10	2.1	.04	2.6	.12	2.7	.19	2.0	.13	3.6	.24
Maintenance, repairs and supplies	14.7	1.46	24.3	1.84	24.0	.41	11.4	.54	9.6	.66	10.3	.67	10.4	.69
Total mine costs	69.6	6.94	74.5	5.66	53.5	.91	66.9	3.16	72.2	4.99	60.9	3.98	69.5	4.58
Taxes and insurance	1.5	.15	1.8	.14	4.4	.07	2.7	.13	3.6	.25	2.3	.15	3.2	.21
Power	5.4	.54	4.5	.34	5.3	.09	2.3	.11	8.9	.61	4.7	.31	5.8	.38
Royalties	1.1	.11	2.1	.16	1.3	.02	2.8	.13	1.1	.08	1.0	.06	—	—
Administration and supervision	3.7	.37	3.2	.24	3.7	.06	6.3	.30	4.6	.32	4.2	.27	6.0	.40
Miscellaneous expense	.3	.03	.4	.03	1.0	.02	.6	.02	.1	.01	.3	.02	.9	.06
Total cost to tipple	81.6	8.14	86.5	6.57	69.2	1.17	81.6	3.85	90.5	6.26	73.4	4.79	85.4	5.63
Tipple and washing plant	1.2	.12	1.4	.11	8.2	.14	4.6	.22	1.2	.09	10.4	.68	5.1	.34
Total cost f.o.b. cars	82.8	8.26	87.9	6.68	77.4	1.31	86.2	4.07	91.7	6.35	83.8	5.47	90.5	5.97
Depreciation	3.2	.32	7.9	.60	7.7	.13	7.3	.34	3.2	.22	9.3	.61	4.3	.28
Depletion	.2	.02	1.2	.09	3.8	.07	1.4	.07	1.5	.10	1.1	.07	.3	.02
Bond and general interest	1.0	.09	.7	.05	—	—	.4	.02	.2	.01	3.3	.22	.6	.04
Distribution	12.8	1.27	2.3	.17	11.1	.19	4.7	.22	3.4	.23	2.5	.16	4.3	.28
Total costs	100%	9.96	100%	7.59	100%	1.70	100%	4.72	100%	6.91	100%	6.53	100%	6.59
Coal produced (net tons)	5,663,614		837,641		2,124,398		2,459,656		427,475		1,273,781		1,248,421	
Tons produced per man-day	2.41		3.46		26.39		6.11		3.68		4.49		4.34	
Revenues	$		$		$		$		$		$		$	
Coal sales	10.33		8.14		2.03		4.96		6.47		6.29		6.90	
Stock adjustments	Cr. .46		.12		—		.12		.28		.26		.64	
Total income	9.87		8.26		2.03		5.08		6.75		6.55		7.54	
Profit (p) or loss (l)	(l) .09		(p) .67		(p) .33		(p) .36		(l) .16		(p) .02		(p) .95	

eastern fringe of the Rocky Mountains. On the other hand, the highest level of production reached on the west coast was achieved prior to 1910 and, in Nova Scotia, only a few years later.

The above figures relate to over-all trends and, therefore, conceal what has been happening to the various grades of coal. Anthracite, which still accounts for about 10% of Canadian consumption, has been almost entirely imported, mostly for space heating purposes.[6] Most of it has been consumed in the central provinces and has come from the hard coal fields of Pennsylvania. Only during the 1930's, when shipments from the United Kingdom and other overseas sources began to match those of the United States has this inward flow tended to show any material change from its traditional pattern.

Coke, meanwhile, has been preponderantly the product of Canadian furnaces both inside and outside the steel industry. Imports have, at times, been received in considerable volume. They have risen rapidly in recent years. Yet, in this case, Canada has also continued to do a fairly large export business as well. These outgoings have, in the main, been from ovens located around the Crow's Nest Pass region of southeastern B.C. and have been destined for nearby metallurgical industries located in the Pacific northwest states.

Section IV: Problems and Possibilities

Compared with the other fuel producing industries on this continent, coal mining has been in difficult straits. Real costs, if not continuing to rise, have merely levelled off. Meanwhile returns, as measured in constant dollar prices at the pithead, have shown a short-run tendency to decline. Caught in this squeeze between a continuing high level of expenditure and dwindling income, a number of the smaller and less efficient mines have had to close down; others, to operate at less than capacity.

These influences have had their greatest impact on underground operations although the tonnage won by strip mining methods has also shown a tendency to fall off in certain areas. Total output in western Canada, for example, has declined by about 40% since 1948. Coal production from the underground mines in both Alberta and southeastern British Columbia is now lower than at any time in the past half century. In Alberta alone, 16 mines were abandoned in 1955. By contrast, the coal mining industries in both Saskatchewan and the older Atlantic provinces have fared much better. Strip mining of lignite south of Regina, largely for industrial purposes, has increased steadily. A rising demand for thermally produced power is also

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[6]The import tariff on coal entering Canada is 50¢ per ton. It applies only to bituminous grades. Anthracite coal and coke, under the GATT agreements of 1948 have been permitted free entry.

causing records to be broken in New Brunswick. In Nova Scotia, only two important pits have, so far, been closed. Production, due more to physical difficulties than to a decline in the market for coal, is currently about 10% below the postwar high achieved in 1950.

However, the outlook in the Maritimes is far from certain. Further mechanization of the face and marked improvements in loading and in underground transportation equipment have helped to minimize certain costs and to offset others. Yet even greater progress will have to be made if the eastern Canadian mines are to acquire new industrial and power markets in competition with oil—outlets which are essential if the prospective fall in coal sales to the railways and for space heating purposes are not to result in a decline in their over-all operations.

The most serious obstacle which the Maritime producers have to overcome are the physical conditions underground. Differing considerably from those which characterize the principal producing fields in Pennsylvania and Ohio, they set a practical limit upon the amount of coal which the average miner, using the best equipment available, can raise to the surface each day. The following statements contained in a submission to this Commission by Mr. L. A. Forsyth, Q.C., President of the Dominion Steel and Coal Company Limited, are descriptive of these conditions:

(1) "At the Sydney Coal Field, the seams are gassy and roofs and pavements weak. Almost all operations are carried out under the sea, necessitating long roadways and much maintenance. The loss of time in transit amounts to nearly two hours daily between the surface and the working faces."

(2) "The operations of the Acadia Coal Company are also beset with physical difficulties. The seams pitch steeply, are extremely gassy, and roofs and pavements require heavy support and much maintenance. In addition, the coals are liable to heat spontaneously."

(3) "At Springhill the seams pitch steeply. Also they are gassy and the roofs require much support. Where pavement and roof are sound, the workings are subject to bumps, necessitating special precautions in the laying out of workings or the avoidance of certain coal-bearing areas altogether."

These physical conditions have made it well-nigh impossible for the companies concerned to utilize much of the equipment which is available elsewhere for mechanized mining. Instead, special machinery and equipment has had to be developed which is consistent with the long-wall system of mining—a system better suited to the mining of these deposits than the room and pillar sequence commonly employed elsewhere in North America. Inherent in this practice are greater costs of roadway construction, operation and maintenance. This, together with the need to make proportionately

heavier investments in long distance underground haulage facilities, has resulted in a cost structure that is both higher and more rigid than those characteristic of the more favourable mining areas of western Canada and the northeastern United States.

Besides the problems of mine maintenance, machine development and high transportation costs underground, there has been a growing need to treat the coal above ground. The newer and larger volume markets frequently call for fuel of a uniform size and composition. Central cleaning and blending plants are therefore necessary. To be most efficient, they must be built on a scale consistent with available markets. If they are overbuilt, their carrying charges will also add, unnecessarily, to the cost of production. In an industry in which the prospective market volume may fall off, rather than increase, such problems as market development, financing and plant optimization are bound to be difficult.

The penalty of distance to markets is greater in the case of coal than in respect to oil and natural gas. It can be reduced considerably by water movement. However, during the postwar period, colliers have rarely been available at rates and in the numbers necessary to carry a large proportion of the Nova Scotia coal up river to Three Rivers and Montreal. A specially-built collier fleet incorporating the latest types of loading and unloading equipment would help to retain certain industrial outlets in Newfoundland and eastern Quebec. The cost of overland movement by rail might also be reduced by selling coal in trainload lots to large-volume users including those purchasing fuel for the production of electric power. More coal might also be converted into electricity at the pithead. Generally speaking, however, transportation considerations are such as to limit the future market for Maritime coal to industrial and power applications in Nova Scotia, New Brunswick and industrial centres on tidewater in Quebec.

Another influence which has its disturbing as well as its reassuring aspects is the increasing efficiency with which coal is being put to use. Coal operators everywhere are faced with the necessity either of encouraging greater economy in the burning of coal or of risking the loss of most, if not all, of their business to other sources of supply. In one application after another, it has become a choice between the lesser of two evils. Greater efficiency in use usually means a short-run decline in volume of sales. Yet it may possibly keep an industry on coal when to do otherwise would almost certainly cause it to choose oil or natural gas instead. By embarking deliberately on such a course, the coal mining industry is at least retaining to itself a more stable and a more lasting market for its output than would be the case were it to ignore the advantage of employing more efficient coal-using equipment altogether.

The changing nature of the market has also had repercussions as to quality. The demand for lump coal is falling off. No longer are the "better

grades" capable of earning such high prices. Too much water or too high an ash content still invites a penalty. Sulphur is also undesirable, particularly in metallurgical operations. However, wet high-ash and high-sulphur coals can be, and are being, used indiscriminately in the production of electricity. Undue friability, a characteristic which at times has limited the use of western Canadian coal, is also less significant. Assuming that the price is right, equipment can be designed or simply bought to handle bulk energy in these forms. Uniformity, but uniformity at a low price, therefore appears to be the dominant influence in so far as the marketing of future Canadian coal production is concerned.

This uncertain picture is somewhat at variance with the longer run prospects which many technologists hold out for coal. Besides its relative abundance, they point to the wealth of organic materials which it contains. It has lost out on grounds of quality in the past but it need not always be offered in the solid form. This handicap is already being overcome in its conversion to electricity. As a gas or liquid, it could be employed in an even wider range of applications. The benefits of automation which are presently accruing to the oil and gas industry could thereby be turned to the advantage of coal at a much earlier stage in its production.

The ultimate, of course, is gasification in the ground. A great deal of work has been done on this in the United Kingdom, the United States and Soviet Russia. Pilot installations have operated with some success in each of these countries. However, their economic advantages have yet to be proven. The resultant gas is low in calorific value. Hence it will not stand transmission over considerable distances. Also, each new coalfield presents a different set of physical problems. Each must therefore be developed independently. A repetition of development expenditures on this scale is likely to be a costly proposition. Also, it is ruled out entirely in such coal mining regions as those on Cape Breton Island in Nova Scotia where the coal deposits, themselves, extend out under the sea.

In this country, more attention is therefore being concentrated on the possibilities of gasification at the surface. Using the latest techniques, pulverized coal can be partially burned in oxygen to produce a high heat value, pipeline gas. Employing a process first developed in Germany and subsequently perfected in the United States, coal can, in this way, be completely converted into a fluid form. No longer do supplementary markets have to be found for coke. By-product chemicals are not necessarily produced by this process. Only sulphur need be stripped out and that in instances where its content is likely to cause undue corrosion in the gasification plant and pipeline facilities. Fortunately, in most Canadian circumstances, it can be sold at a profit to pulp and paper mills nearby.

Yet for the over-all project to be worthwhile, the coal must be extraordinarily cheap at the mine. In western Canada where clean, dry natural

gas is readily available, a direct B.t.u. comparison illustrates its lack of feasibility there. The coal equivalent price of the natural product is often as low as $2 a ton at the field. Besides, allowances would have to be made for the cost of building and operating the necessary gasification facilities. Oxygen would also have to be purchased in large quantities. Obviously the field price of natural gas will have to rise considerably before this type of coal-based operation becomes commercially attractive in the western Prairie provinces or British Columbia.

Elsewhere the alternative is the gasification of oil. Crude petroleum and any one of its products can be similarly processed with oxygen and any one of its products can be similarly processed with oxygen to yield a substitute for natural gas. Even residual oil is a less complex substance than coal. The necessary gasification plant is therefore less complicated and less expensive to build. Both maintenance and operating costs are lower. The technology in respect to oil is already well developed. Many an oldtime artificial gas producer is now using oil in this way to supplement his manufactured gas capacity based on coal. It follows that as long as oil, in its cheaper forms, is available at prices comparable with that of coal, the former will have a decided advantage in so far as gas production is concerned.

Eventually, of course, oil as produced in the conventional manner, will be running out. Even before 1980, demand in some areas of North America may be moving sufficiently ahead of supply to necessitate the production of liquid hydro-carbons from alternative source, such as natural gas, the oil shales, Alberta's tar sands and even coal. A good deal of the technology is already available. Germany fought the latter years of World War II largely on its supplies of coal-based oils. Yet there is also the matter of location. Many coals are suitable for this purpose. Those close by North America's principal centres of population and industry will probably be the first to be developed with this end in view. Canada's coal fields, being unfavourably situated in this respect, are likely to be passed by, at least for several generations.

To one concerned with the next 20 to 30 years in Canada, the more humdrum aspects of production and distribution are likely to be the most relevant. In order to cut costs, the number of man-hours spent above ground, in transit and in actually digging out the coal must be reduced, and reduced substantially. Machinery will perform this task. Yet frequently the mine must be adapted to the machine rather than the machine to the mine. Continuous mining helps. In many places the modern miner can cut more coal than can be effectively hauled away to the surface. Better-engineered and more comprehensive conveyor systems are therefore required to bring about a genuine speeding up in over-all productivity. Closer integration between different pits in the same coal field, and even between different coalfields, may also pay dividends in this respect. Central crushing, screening, washing and drying plants can be employed more effectively if

they can be operated around the clock. By blending, the output from different sources can be converted into a more uniform product. This is what the market requires and this is what the coal industry will have to provide if it is to resist the continual incursion into its hard core markets by oil and natural gas.

All this requires capital. Planning on a large scale and for many years ahead presumes both a high level of investment and comparatively low rates of interest. The resultant operations must also promise to be reasonably continuous. Only if this is so can the high carrying charges be met. Firm markets of 10 or 20 years duration may have to be contracted in advance. Without them, financing may be impossible. This being so, the very structure of coal mining appears to be for a change. Only the large organizations with strong corporate ties in other fields are likely to survive. Meanwhile small, non-integrated mining companies will find it increasingly difficult to exist on the basis of spot sales in the open market.

For a time we may merely witness a continuation of the present trends. Coal will be converted more and more to electricity at the pithead. Pithead generation, in turn, will tend to concentrate in those areas where coal of a uniform quality can best be produced by mechanical methods. Like the power utilities, some of the metallurgical companies will also be buying up their own captive mines. Their incentive to move to the source of supply, however, is much reduced. They may therefore operate at a distance drawing their supplies, if at all possible, by water to the continent's major centres of industrial activity.

Section V: Demand-Supply Trends 1955-80

For forecast purposes, the nation's coal requirements have been assessed in two quite different ways. Prospective requirements have been estimated regionally, province by province, across the country. A separate analysis by principal end-use has also been carried out. In both instances the relative price movements of alternative fuels have been taken into account as have possible trends in the cost of producing and transporting coal from the mines to its point of ultimate consumption in this country. The results of these two studies, which were subsequently reconciled, point to a marked change in the relationship between Canadian production and imports over the forecast period under review.

In total, Canadian coals are expected to go on falling until sometime in the mid-1960's. Thereafter, with the demand for coking coal in the nation's steel plants and other metallurgical establishments continuing to expand and with the growing need on the part of many electrical utilities to resort to thermal sources of power, a reversal may well set in. Progressively greater supplies may consequently be called for. Nuclear power if it becomes competitive, would moderate this upward trend in the 1970's. But even if

this comes about, consumption of coal in Canada may, by 1975, have passed its all time high (recorded in 1948) of 48 million tons. Around 1980, and depending upon the ability of atomic power plants to intercept a portion of this demand, the nation's requirements may well exceed 55 million and may possibly be approaching 80 million short tons annually.

These expectations, portrayed in the chart Coal in Canada, 1926-80—Consumption by Principal End Use can also be summarized as follows:

Estimated Consumption of Coal by Principal End Use
(in millions of short tons)

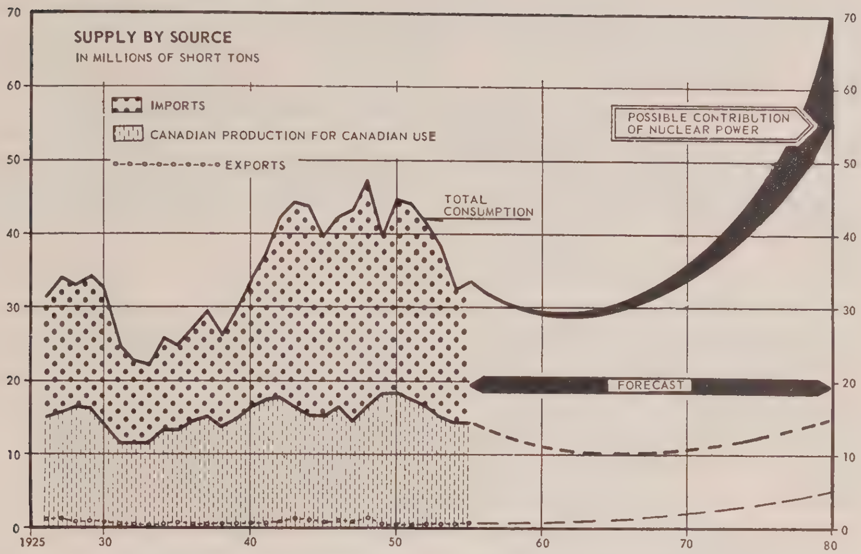
	1955[a]	1965	1980
Space heating	8.3	3.0	2.0
Transportation	6.0	1.3	0.5
Manufacturing and mining	10.5	10.3	13.0
Coke making	5.5	8.0	15.0
Electric power	1.8	6.0	22.5 — 40.0
All other[b]	1.7	1.8	2.0 — 8.0
Total consumption	33.8	30.4	55.0 — 78.5

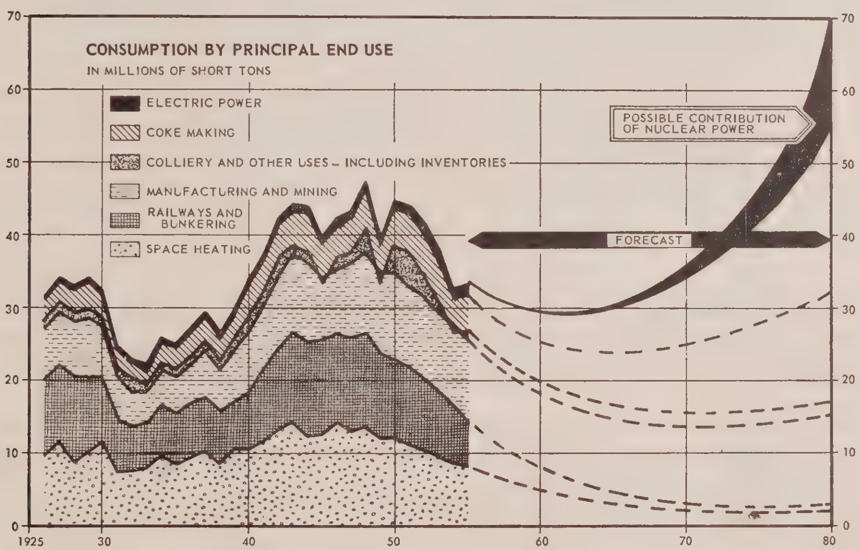
[a]Preliminary.
[b]Includes colliery use, mine waste and inventory changes.

As recently as 1950, the two largest uses of coal in Canada were space heating and transportation. Residential and commercial uses, the railways, and ocean-going shipping together bought more than half of all the coal marketed in this country. Over the past half-dozen years, however, a marked conversion to oil has taken place. Now natural gas supplemented, particularly in western Canada, by the natural gas liquids is also making considerable headway. So much so that, by 1965, conversion to liquid fuels by these uses may have effected a 75% reduction in the total purchases of coal. (See chart: Bituminous and Lignite Coal Consumption, 1926-55.) From buying something in excess of 23 million tons of coal annually in 1950, consumers in these use categories may have cut their yearly needs back to less than five million tons a decade from now.

Other declines, some of them of a less persistent nature, can also be anticipated. With distributors offering natural gas throughout British Columbia, the eastern Prairies, Ontario and as far eastward as Quebec, the manufacture of artificial gas from coal will be largely discontinued. A number of the nation's older coking plants will, consequently, be closed down or simply reserved for peak shaving purposes only. Colliery use and wastage, roughly paralleling the output of Canadian mines may also bottom sometime in the 1960's. Industry, too, may take less coal. More manufacturing concerns will doubtless convert either to natural gas, offered on an interruptible basis, or continue to convert their equipment to the burning of residual oil. Also, either or both of these fuels may prove attractive to

COAL IN CANADA – 1926–1980





concerns whose operations lend themselves to the installation of dual-firing equipment.

Meanwhile, a few industries, particularly those concerned primarily with price of energy in bulk rather than quality may follow the opposite course —that of stocking coal to carry them round the year. Some pulp and paper mills, chemical plants and building material and machinery and equipment manufacturers in eastern Canada are cases in point. They will consume coal largely as a boiler fuel. Yet, all things considered, it is with the coke using metallurgical industries and electric power utilities that the main hopes of the coal industry rest. They, and they alone, will make possible the gradual return of coal to a position of first rank importance in Canada's energy producing economy some 25 years hence.

On the supply side, a number of questions remain to be answered. Where, in the late 1960's and 1970's, will this additional coal come from? Will it be supplied substantially from United States sources? Or will Canadian mines be able to improve their position relative to imports? Also—and this is very important structurally to the industry—what do these trends mean as between strip and underground mined coal? It would seem that, with quality becoming progressively less important, production from mines of the former category would become dominant, particularly in western Canada.

Due to the limited transportability of coal, our examination of the nation's supply prospects must necessarily be regional in character. Consumption in all uses in the four western provinces turned downward for the first time in 1949. Production in British Columbia, Alberta, and Saskatchewan began to drop in the following year. From around 12 million tons in 1950, it had already fallen to about eight million tons in 1955. Nor is the period of adjustment over. The industry, after a careful review of its markets, has recently forecast that its output of all coals—bituminous and lignitic—will be less than 5.5 million tons in 1960.[7] Our own studies of demand show the prospects with regard to sales to be even more limited in the years immediately thereafter. Indeed, it is quite possible that, confronted with local surpluses of any and all types of fuel, coal production in western Alberta and British Columbia may not begin to pick up until 1970 or later.

Mention has already been made of the growing importance of strip or open cut mines. Many of them, developed to gain a quick increase in output during World War II, have continued in operation. They and their successors, due to lower average costs and the economies which can be effected by the latest types of earth and rock moving equipment have taken over many of the markets formerly enjoyed by the underground mines. As a result, strip mining, which accounted for little more than 20% of western Canadian output in 1945, provides more than 50% at the present time.

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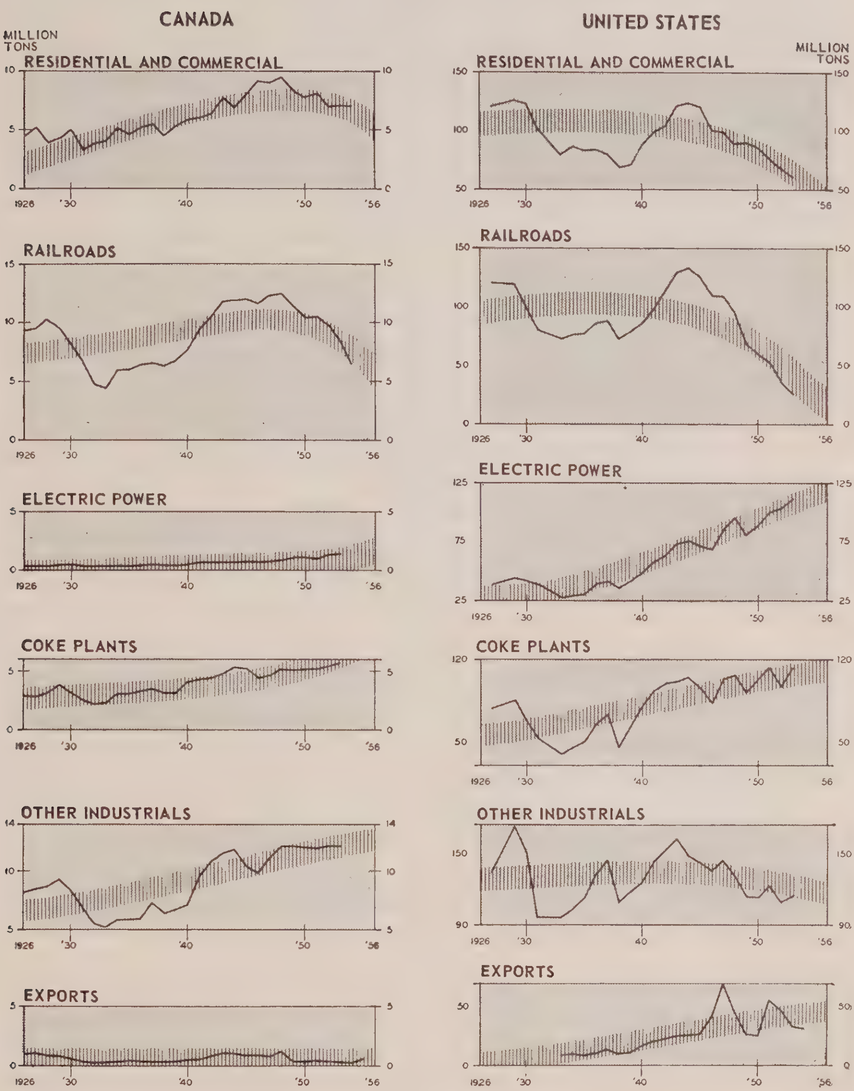
[7]See submission of the Coal Operators Association of Western Canada to this Commission, dated November, 1955.

BITUMINOUS AND LIGNITE COAL CONSUMPTION
1926–1955



OTTAWA 1956

This, furthermore, is a revolution which is far from being complete. Again referring to the brief submitted by the coal operators, it would appear that strip mines may account for two-thirds or more of all the coal raised in western Canada in 1960.

For purposes of this report, total requirements in western Canada in 1965 are placed at some four million tons. By 1980, on the other hand, they could be upward of 10 million tons. The growing needs of the electric power utilities will make most if not all of the difference. Some may even be exported in this form to utilities and other users in the Pacific northwest states. One or more steel industries located along the Pacifiic coast could also make a substantial difference. Drawing their supplies of coking coal from captive mines in and around the Crow's Nest Pass area of British Columbia and Alberta they alone might make possible yearly exports to the extent of several millions of tons.

In the Maritimes, production is unlikely to fall off either as rapidly or as far. Market forecasts, prepared by those of the Commission's staff concerned with energy and independently by the industry itself generally point to a decline in over-all sales of Nova Scotia and New Brunswick coal of between 10% and 20% between now and 1960. At the same time pronounced shifts are forecast both as to destination and in respect to end use. Generally speaking, however, increased exports overseas and a greater volume of sales to the power producing utilities are expected to offset lower shipments to the railways and through wholesale and retail outlets to household, commercial and small and medium sized industrial customers.

Output thereafter may be maintained at or about the six million ton a year level. Pithead real costs, now on the decline, may be reduced further by mechanization.[8] This should enable the industry to retain more of its existing outlets in direct competition with oil. Also, while nuclear power may eventually have an application in the Maritimes, it may not be available at a price and in plant sizes suitable to local power requirements much before 1975. Thus, while oil and other imported liquid fuels may meet most if not all of the growth requirements of the region after 1960, locally produced coal may be needed in a number of large volume energy consuming applications in the 1970's and 1980's.

While total Canadian production may be in for a revival after 1970 it will, by then, be overshadowed by the great increase in imports which may have begun to take place in the middle 1960's. Ontario thermal power plants, alone, may call for some nine million tons of American coal a year in 1970; over 20 million tons in 1980. The steel industry in central Canada may absorb another 12 million tons 25 years from now. These will be principally coking coals from Pennsylvania and Ohio. Also, because natural

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[8]See *The Nova Scotia Coal Industry* by Urwick, Currie Ltd., and published by this Commission.

gas will be relatively expensive in Ontario and southern Quebec, coal from the United States may retain a much larger share of the industrial market than has been forecast for western Canada. Facilitated by the completion of the St. Lawrence Seaway, these requirements could amount to ten or more million tons a quarter century from now.

Drawn together these expectations as to Canadian production, imports, exports and the amount of coal supplied for country may therefore run somewhat as follows.

Estimated Coal Supplies in Canada
(in millions of short tons)

	1955	1965	1980
Production	14.6	10.8	16.0 — 24.5
Imports	19.7	20.0	41.0 — 62.0
Exports	0.6	0.5	2.0 — 8.0
Supply	33.7	30.3	55.0 — 78.5

7

THE PETROLEUM INDUSTRY

Section I: Introduction

Measured either in bulk or value terms, petroleum is now the most important commodity entering international trade. A relative newcomer, it has leapt to prominence over the last half century. Now providing more energy than any other source, oil already meets almost half of North America's needs, and is rapidly forging to the front in many other parts of the world. For this reason, and because large scale petroleum reserves are known to exist in relatively few countries, the discovery of large oil reserves in western Canada is of major significance in this country's economic development.

There have been two definite phases in the use of petroleum, and a third is under way. The first, which began soon after 1860, might have been called a kerosene economy. Light petroleum fractions were soon accepted as a cheap and efficient substitute for coal oil. Other fractions, which make up the rich and complex mixture of hydrocarbons in crude petroleum, ranging from explosively volatile wet gases to heavy oils, waxes and asphalts, were beyond the technology of the day to unravel, and the capacity of the then existing economies to absorb. At that time such by-products as gasoline were a serious problem, and their disposal involved great waste. Indeed, it was not until about 1910 that motor fuel requirements exceeded for the first time those of kerosene.

World War I and the maturity of the internal combustion engine marked the second phase. Within the space of a few years, the more volatile fractions which refineries had been throwing away were engulfed by the rising demands of the automobile industry. The price of gasoline rose sharply and drilling activity increased all the world over. Exploration soon yielded results in Texas, California and Venezuela, and by 1930 surplus oil production had become general once more. Indeed, from then until World War II, there was surplus capacity in almost every branch of the industry. With kerosene consumption declining and a gasoline economy becoming

general, the unwanted middle distillates overhung the market and frequently sold at distress prices. Heavy residual oils were even more of a problem. Often they were dumped into adjoining rivers and streams or sold at prices far below that of the crude oil itself.

Phase three, which developed out of World War II, is now asserting itself. For the first time in history, most refineries have few surplus products. Nearly everything from a barrel of crude is being marketed, production in its numerous phases being geared much more closely to fluctuations in demand. Behind all this lies the modern refinery equipment and techniques, which are being used to crack heavy fractions down to lighter ones and, more important still, the domestic oil heater and the diesel engine. Indeed, the consumption of middle distillates has been increasing much more rapidly than that of gasoline in recent years, and it now serves to underwrite much of the growing demand for crude oil itself.

Although the history of the Canadian crude oil industry dates back almost 100 years[1], production did not begin to reflect the amount of exploratory drilling done in western Canada until well into the 1930's. Then, in 1936 Turner Valley was definitely established as the first major oil field in the British Commonwealth. Scattered discoveries of little commercial importance had been made prior to this and natural gas had been found in abundance. However, with the exception of the modest production which had been obtained from the shallow Ontario fields from 1860 onward, Canada had little in the way of a crude producing industry.

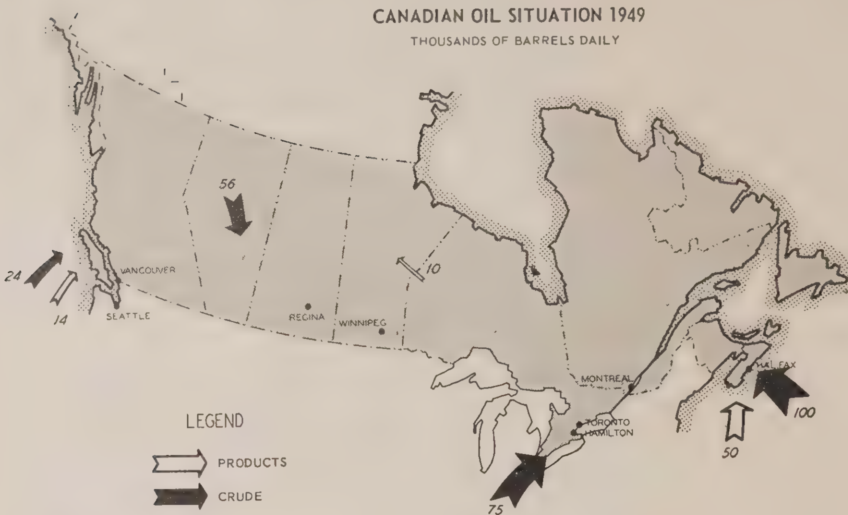
After that the tempo of discovery began to increase. First, the heavy crude area along the Alberta-Saskatchewan boundary near Lloydminster was opened up. Then, early in 1947, light oil was discovered on the plains near Edmonton at Leduc.

In the short space of ten years the Canadian oil outlook has been transformed. (See chart: Canadian Oil Situation, 1949 and 1955.) In 1947, domestic sources supplied less than 10% of the nation's needs. Since then, production has risen more than twentyfold and, despite the rapid rise in consumption, existing wells are now capable of producing enough oil to meet the nation's over-all petroleum requirements. Several major oil fields and many smaller ones have since been discovered and recoverable reserves have sky-rocketed from a mere 70 million barrels in 1946 to around 3,000 million barrels at the present time.[2]

Measured in dollar terms, these developments appear even more impressive. Valued at over $300 million in 1955, output at the primary level

[1]It is now known that the first successful oil well on the North American continent was dug in Lambton County, Southern Ontario early in 1858. This was months before the much publicized pioneer Drake well was drilled in Pennsylvania in 1859.

[2]More precisely, 72 million barrels at the end of 1946 as opposed to 2,757 million barrels (inclusive of 250 million barrels of natural gas liquids) on December 31, 1955.


CANADIAN OIL SITUATION 1949
THOUSANDS OF BARRELS DAILY
56
10
24
14
VANCOUVER
SEATTLE
REGINA
WINNIPEG
MONTREAL
TORONTO
HAMILTON
HALIFAX
100
50
75
LEGEND
PRODUCTS
CRUDE


CANADIAN OIL SITUATION 1955
THOUSANDS OF BARRELS DAILY
1
PRODUC
310
51
31
11
61
18
SEATTLE
32
52
28
113
1
PRODUCTS
15
4
PRODUCTS
MONTREAL
PORTLAND
TORONTO
210
63
27
23

already exceeded that of any other Canadian produced mineral. Sales on all levels including pipeline transportation, refining and product marketing amounted to more than $1 billion last year. This being our measure, the petroleum industry in this country would now appear to lead all others except agriculture and, possibly, pulp and paper. Its outlays on exploration and development, new refinery and pipeline construction and on repair and maintenance are even more exceptional. In 1955 alone, firms operating in Canada spent well over half a billion dollars in the search for additional reserves and in creating new transportation, processing and distributing facilities. From one of the nation's lesser activities the petroleum industry has already leapt to prominence. If recent trends can be taken as any guide, its contribution to Canada's future economic development may be even more spectacular.

Section II: World Setting

In any review of the growth of the Canadian oil industry, reference to the world developments is necessary to give proper perspective. How important, in this setting, is Canadian production and consumption? And, given a continuation of present trends, what role is Canadian oil destined to play in the world's trade in crude oil and manufacture of petroleum products?

The answer to the first of these questions is easily determined. Still in its infancy, the Canadian oil industry produces less than 3% of the world's total output of crude petroleum. As for reserves, about 1.5% of the world's proven capacity has now been found here. When it comes to quantities used, Canada's record is somewhat more impressive. About 4% of world production is now being consumed in this country.

The answer to the second question—"What role is Canadian oil likely to play in the future?"—is more elusive. Oil, at least in its crude form, is a freely traded commodity. The supply and demand for petroleum is, therefore, influenced by numerous factors, many of which are outside the control of any one country. Reserve and cost of production prospects must be taken into account. So must the likely trends in consumption by major product and by principal end use. In approaching this subject, let us begin by going back a few years, thereby obtaining a better grasp of world developments and their effect, to date, on Canadian production and the Canadian market for petroleum products.

The international oil industry, as we know it today, dates back barely a century. Even at that, production was small. Only a few scattered discoveries were made prior to 1900.[3] Most of the world's major oil produc-

[3]Canada (1858), United States (1859), Rumania (1857), Russia (1863), and the Dutch East Indies (1893).

ing regions have been developed during the past 50 years. This is true, not only of the Caribbean and Middle East production, but also of the United States Gulf coast, east Texas and California as well.[4]

Production has risen steadily in response to new and expanding demands for mineral oils. From obscurity 100 years ago, oil production rose to 210,000 barrels a day in 1890. It first passed one million barrels a day in 1912 and ten million barrels a day in 1949. World production in 1955 exceeded 15 million barrels a day, with the United States supplying about 45% of this amount, the Middle East 21%, Venezuela nearly 15%, and the Iron Curtain countries about 10% of the total.[5] (See chart: Crude Oil Production and Reserves.)

The number of areas where petroleum production has, so far, turned out to be commercially profitable is limited. Ninety per cent or more of the world's proven reserves are located in two principal areas; that is to say, in fields bordering on the Gulf of Mexico and the Caribbean Sea and in the Middle East. So far, the existence of 200 billion barrels of oil has been established. Equivalent to 40 years of supply at current rates of consumption this vast reserve is distributed between the Eastern and Western Hemispheres in the ratio of about 3:1. The Middle East is at the top of the list with about two-thirds of the known reserves. The United States is now in second place with about 15%, followed by Venezuela with 7% and the Communist bloc with about 6%.

Of all the producing areas, the Middle East is by far the most promising. This is due to the fact that development costs are low and average output per well is so much higher there than in the United States and elsewhere. This is illustrated by the fact that the average well in the Middle East fields is currently producing around 5,000 barrels a day, some yielding as much as 15,000 barrels a day. Fewer than a thousand wells are all that are needed to maintain the present level of output for a decade or more.[6]

In the United States the situation is quite different. By contrast, there are about 550 thousand producing wells. These average about 12 barrels a day, although, of course, there are much larger producers in some fields. For the world as a whole, average production per well is only about 20 barrels per day, largely due to the low American average.

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[4]California (1900), Mexico (1901), United States Gulf coast fields (1901), Oklahoma (1904), Illinois (1906), Trinidad (1909), Iran (1913), Borneo (1913), Venezuela (1920), Iraq (1927), east Texas (1930), Bahrein (1932), Saudi Arabia (1936), Kuwait (1946).

[5]In 1954, United States interests controlled 68% of the world's crude petroleum production; British and Dutch capital 16%; other private organizations 3%; the U.S.S.R., 10% and other governments 3%.

[6]There are now some 35 producing fields in the Middle East; two thirds of these constitute 95% of the proven reserves there.

These figures taken by themselves can be misleading. Reservoir conditions (and hence maximum efficient rates of output) vary considerably from one producing region to the next. Secondly, few fields produce at a uniform rate up to the point of exhaustion. The astonishing output of the Middle Eastern countries and, to a lesser extent, the Caribbean area characterizes young fields which are likely to be productive, albeit at a declining rate, over a good many years. On the other hand, some fields in the United States are relatively old and over-exploited. They are, consequently, no longer able to produce oil at the rates which they attained in the past.

In assessing productive capacity of various oil-producing areas, development costs must also be taken into account. Certain oil fields possess thick and extensive underground oil bearing reservoirs of highly porous and permeable rock in which oil has accumulated under suitable stratigraphic and structural conditions. Under these conditions, wells can be spaced far apart and withdrawals can take place at a relatively high rate. Average drilling and operating costs can, consequently, be kept to a minimum. In the Middle East, geological conditions are almost ideal in this respect and, while heavy outlays may be necessary in the first instance, fewer wells are needed and investment costs can be written off against a much greater volume of production. On the other hand, where oil is found in small pockets and the rock through which it must move is relatively impervious, numerous wells must be drilled to find these formations and development and operating costs are consequently much higher.

In the United States, where only a few fields have been as productive as those in the Middle East, average exploration and development costs per barrel of reserves are now tending to rise. Industry reports indicate that it now costs as much as $1.50 a barrel to find and develop oil there.[7] By contrast, exploration and development outlays are only 20 to 30 cents per barrel of reserves in the Middle East.[8] Recent Canadian experience in this connection has averaged out at around $1 per barrel of reserves.[9]

Due largely to the fact that the petroleum industry really began and was subsequently developed more extensively in the United States, this continent has produced far more oil than all other areas in the world taken together. The United States alone has recovered 60% of all the oil so far brought above ground. Surprisingly enough, these heavy withdrawals have not yet seriously affected the American reserve position. In fact proven reserves

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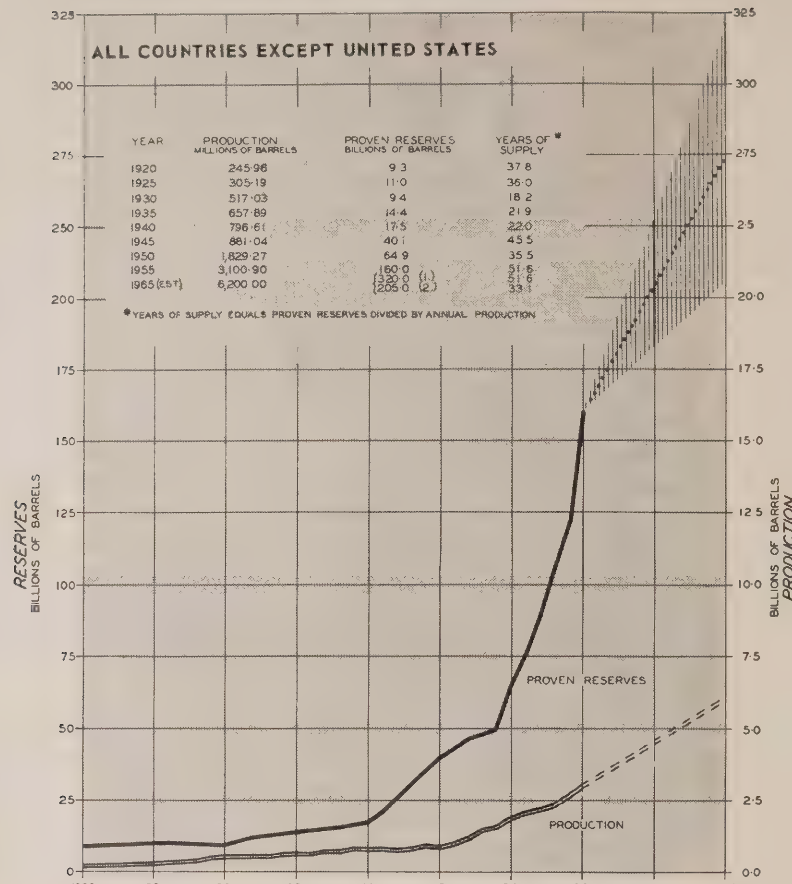
[7]See *Joint Association Survey* made by the American Petroleum Institute, the Independent Petroleum Association of America, and the Mid Continent Oil and Gas Association, the results of which were released in June, 1956.

[8]According to B. Schwadran in his recent book, *The Middle East, Oil and the Great Powers,* pub. F. A. Prager, New York, 1955, "The Chairman of the Board of Directors of the Bahrein Oil Co. testified that the cost of producing a barrel of oil in Bahrein was 25 cents including the royalties to the Sheik."

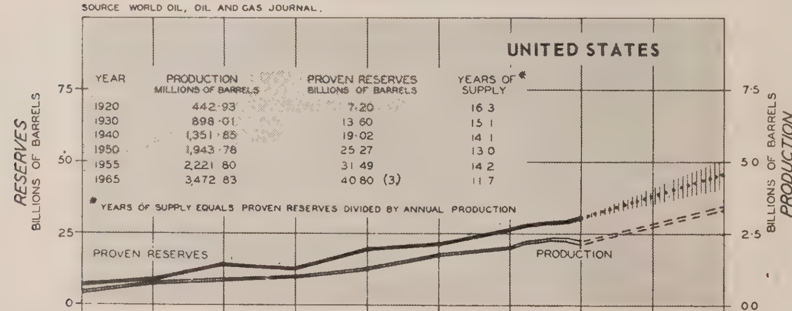
[9]See Appendix A.

CRUDE OIL PRODUCTION AND RESERVES



(1.) ASSUMING EXPLORATION AND DEVELOPMENT ACTIVITY COMPARABLE TO THAT OF 1950—1955
(2.) ASSUMING VIRTUAL CESSATION OF EXPLORATION AND DEVELOPMENT IN THE MIDDLE EAST

SOURCE WORLD OIL, OIL AND GAS JOURNAL.



3 COMPOSITE OF INDUSTRY FORECASTS.

SOURCE: PRODUCTION DATA TO 1955: U. S BUREAU OF MINES.
OTHER: WORLD OIL, OIL AND GAS JOURNAL.

UNITED STATES AND FREE WORLD DEMAND AND PRODUCTION TRENDS, 1920 – 1965

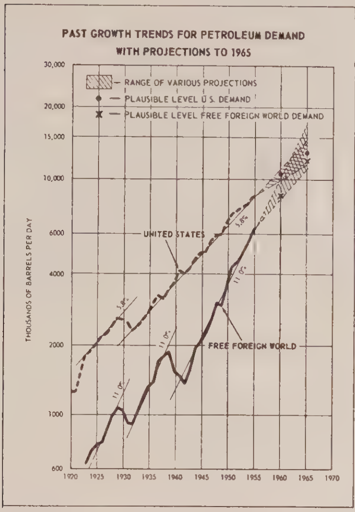


FIGURE 1 – Rate of Growth of Oil Demand in the United States and the Free Foreign World by Years, 1920-1955, with Projections to 1965. Source of Domestic Data – U.S. Bureau of Mines. Source of Foreign Data – Various Industry Estimates, and Extrapolation in Earlier Years on Basis of Production Figures.

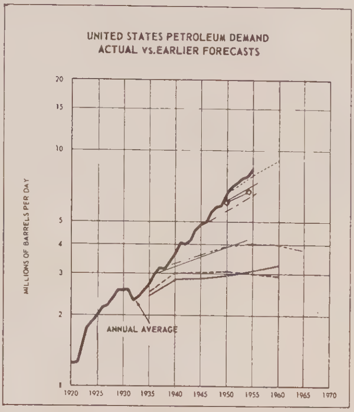
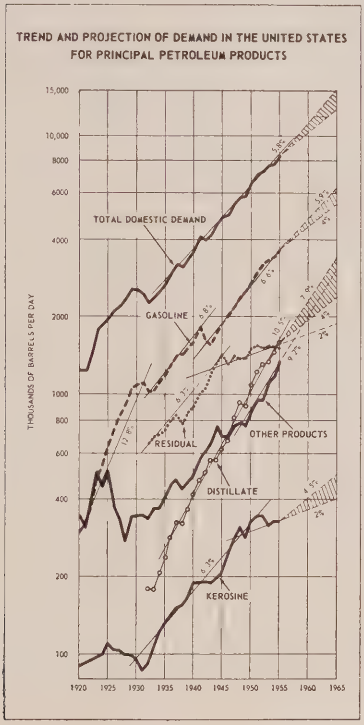


FIGURE 2 – Trend of Oil Demand in the United States by Years, 1920-1955, with Supplementary Curves Showing Various Forecasts Made in the Past. This Chart Illustrates the Tendency to Underestimate the Strength of the Growth Momentum.



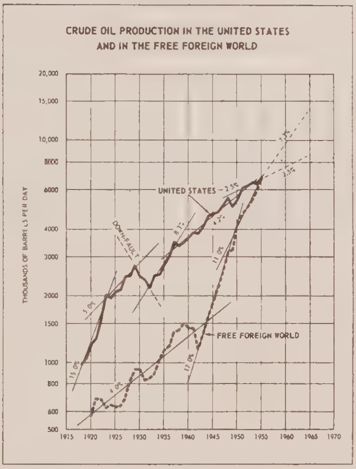


FIGURE 4 – Trend of Crude Oil Production in the United States and the Free Foreign World by Years, 1917-1955, with Projections to 1965.

FIGURE 3 – Rate of Growth of Demand for the Principal Petroleum Products in the United States by Years, 1920-1955, with Projections to 1965.

SOURCE: *PETROLEUM DEPT., CHASE NAT. BANK FEB. 1956*

have continued to rise more or less in step with demand. Thus industry in the United States has been able to count on anywhere from 10 to 15 years of future supply ever since 1920. This has happened despite the enormous increase which has taken place in petroleum consumption. (See also chart: United States and Free World Demand and Production Trends, 1920-1965.

Proven gas reserves, on the other hand, have varied both up and down. Today, they are equal to about 22 years consumption as compared with 30 years in 1946 and as little as 12 years in 1929. Yet, each upsurge in demand has, within a few short years, resulted in the proving up of even greater gas reserves. Small wonder that there is a disposition on the part of these industries to look ahead in terms of decades rather than years and to assume that progress and expansion inevitably go hand in hand.

There are other grounds for optimism. Although the United States has been more thoroughly explored than any other part of the world many other favourable areas still remain virtually untapped. One might include in this category the great sedimentary basin of New Mexico, Nevada, Arizona and the other Rocky Mountain states. One might point to the extensive tidelands which fringe the Gulf of Mexico and to the west coast of California. And, as a Canadian, one will also tend to keep an eye on the Williston Basin—those thousands of square miles of territory which include most of the Dakotas, part of Montana and push up into southern Saskatchewan and southwestern Manitoba. Each one has great possibilities. Yet their true potential will never have been confirmed until untold numbers of wells have been drilled deep into their formations, probing for the oil which so often has escaped other means of detection.

The extent of exploration is one thing; the efficiency of recovery another. No doubt great improvements will also be made in this direction. To date something less than one-third of the oil in place can be considered as proven reserves, or oil which will eventually be produced. But the oil industry's technology is ever on the move. New secondary recovery methods are being evolved which promise to raise the recovery factor to 60% or better.

So, in North America, the oil industry has not only one but two good reasons for optimism. One is the tremendous extent of the probable and possible oil country. The other is the substantial reduction in the amount of these energy resources left as unrecoverable in the ground.

But what of the other major oil producing regions of the world? Already, as we have seen, they have turned out to be more productive than fields on this continent. Tremendous reserves have been established with much less effort.

Few geologists have been prepared to estimate the total amount of petroleum which may ultimately be recovered from the world's sedimentary rock formations. However, the types of structures in which oil is more

likely to be found are, technically, becoming better understood. Some experts believe that as much as 1,000 billion barrels of petroleum will eventually be obtained from the world's oil-bearing rocks. They have placed the amount which may be recovered from structures under land areas as being in the order of 500 billion barrels, approximately five times the world's total production to date. The remaining oil reserves, they think, may ultimately be recovered under the shallow waters which cover the continental shelves.

As to the likely distribution of these possible oil reserves, it has been calculated that of those under land areas, around one-third are yet to be discovered in the Western Hemisphere. The remaining two-thirds occur principally in central Asia. Perhaps as much as one out of every four barrels of these potential reserves are in the Russian dominated zone, the remaining three barrels being under the control of or accessible to the Western democracies.[10]

The above estimates have been based largely on our knowledge of known oil-bearing formations. However, since past experience has shown that petroleum has also been discovered in unpredictable areas, these figures may well be on the conservative side. Even if one assumes a doubling every ten years of the world's oil consumption, it looks as if no serious worldwide shortage of liquid fuel is likely to be encountered before the end of the present century. (See chart: Possible Petroliferous Areas and Proven Reserves 1945, Mid-1956.)

So much for the world's oil producing potential. Now let us review briefly the changing pattern in world trade. For a time, the United States was the world's principal exporter of crude oil and petroleum products. Then, as domestic needs began to occupy more and more of that country's capacity, first Mexico and then Venezuela assumed the role of the principal supplier of European and other overseas requirements.

Development of the Middle East fields was delayed by ignorance of their true potential, political unrest and a lack of nearby markets. Early successes, the glowing terms in which the De Golyer Commission of 1944 described Middle East oil possibilities, together with the construction of long-distance pipelines and large tankers, helped to overcome this. In addition, improved refining techniques have overcome the sulphur and other quality disabilities of the sour crudes coming from the Persian Gulf region. In the postwar period, currency considerations have also been important. The United Kingdom, and other European countries have turned more and more to the Middle East since oil from this source, besides being cheaper, usually involves fewer dollars than purchases from either Venezuela or the United States Gulf coast.

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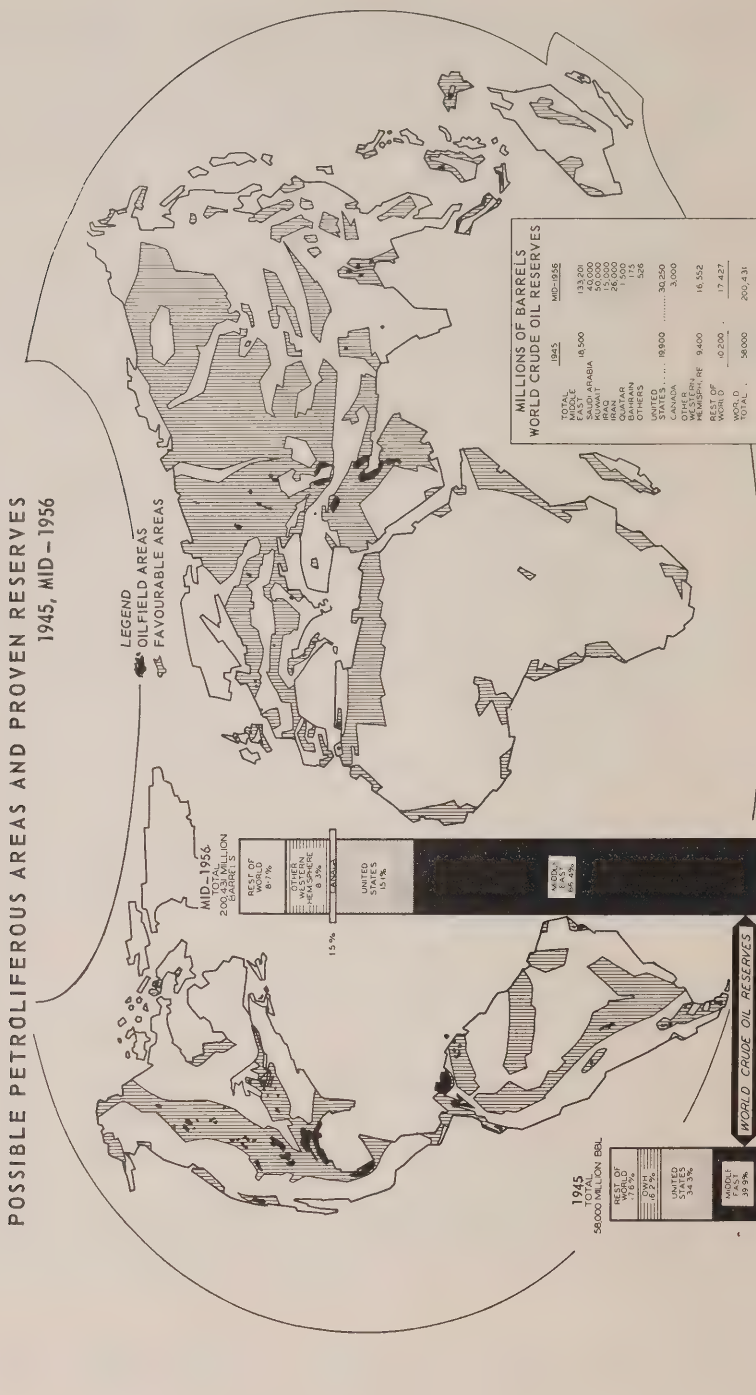
[10]See *Oil Resources in the Next Half Century* by D. C. Ion, British Petroleum Company, pub. June, 1956.



	1945	MID-1956
TOTAL MIDDLE EAST	18,500	133,201
SAUDI ARABIA		40,000
KUWAIT		50,000
IRAQ		15,000
IRAN		26,000
QUATAR		1,500
BAHRAIN		175
OTHERS		526
UNITED STATES	19,900	30,250
CANADA		3,000
OTHER WESTERN HEMISPHERE	9,400	16,552
REST OF WORLD	10,200	17,427
WORLD TOTAL	58,000	200,431

For years there was a tendency for crude to be refined close to the oil fields. This was true, particularly in countries like Venezuela and Iran.[11] Very large refineries were constructed there and the resulting products were moved by tanker to the world's markets. This now appears to have been a passing phase. Long distance transmission lines, the desire to save foreign exchange and the need for refinery by-products have stimulated the construction of refineries close by their principal markets.[12] These are the main reasons why pipelines have been built from the Persian Gulf to the Mediterranean and why a number of refineries have been brought into operation in Western Europe since the end of World War II.

World shipments of petroleum products, such as gasoline and fuel oil, have been comparable in volume with those of crude oil. From now on, however, shipments of crude oil will probably assume increasing importance and, unless producing countries invoke additional legislation[13] insisting that the natural product be processed at home, most of the newer refineries will continue to be built close by the world's main industrial centres.

Reference has already been made to the fact that the United States is no longer the world's principal exporter of crude oil and petroleum products. Indeed, except in periods of emergency, American exports soon will be small relative to the global supply. In all probability they will consist of small quantities of selected crudes and a limited amount of such special products as aviation gasoline, kerosene and lubricants.

Meanwhile, shipments from Caribbean countries—and this is particularly true of Venezuela—have been increasing rapidly in recent years. Indeed, tankers from Latin America now supply by far the largest part of United States imports. They are also moving very large quantities of crude and residual fuel oil to eastern Canada, having largely displaced United States Gulf coast oil from its traditional outlets in the Maritimes and Quebec. And they are still one of the major dollar products moving into sterling and other soft currency markets. (See chart: World Oil Trade—Selected Years in Thousands of Barrels Per Day.)

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[11]The world's largest refinery with a capacity of more than 550,000 bbls/day is at Abadan in Iran. Other refineries in the Middle East are on Bahrein Island (186,000) and at Raz Tanura (140,000). Others in Latin America are at Curacao (200,000) and Aruba (440,000), both in the Netherlands West Indies. By comparison the largest refineries in the U.S. include those at Whiting, Ind. (212,000); Baton Rouge, La. (266,000); Port Arthur, Texas, (245,000) and Bay Town, Texas (260,000) bbls/day.

[12]For instance, refinery capacity in Europe was increased from 520,000 bbls/day at the end of 1949 to over 2,210,000 bbls/day by the end of 1955.

[13]The concessionaire is obliged to refine in Venezuela at least 10% of the production which it obtains from its own crude sources in that country. Also, of the remaining 90%, none can be refined in the general Caribbean area. Special tax exemptions are granted to companies processing their own production in whole or in part in Venezuela whereas higher royalties were levied in 1956 on Venezuelan crude refined outside the country.

The Middle East has become the predominant supplier of European industry. Now, most of the British Commonwealth and the Far East are becoming dependent on its oil fields and refineries. Surplus crude, from countries bordering the Persian Gulf, has even been finding its way across the Atlantic to Montreal and the east coast of the United States. With tanker design no longer a limiting factor, the movement in this direction will, in all probability, increase.

In the East Indies, production has recovered gradually from the ravages of World War II. In comparison with the Middle East, however, its production and exports are small and of a subsidiary nature. At present there seems to be little prospect of crude oil or refinery production in Indonesia and other Far Eastern countries expanding beyond the market requirements of their immediate vicinity.

In future, it looks as if most of the crude oil and products produced in the Western Hemisphere will be consumed there, with the United States constituting by far the most important market. Europe's needs, meanwhile, will be met mainly from the prolific reserves of the Middle East, with crude oil movements becoming progressively more important. This will be accompanied by a decline in the cross shipment of crude, and especially products, from the Caribbean area to Western Europe. With regard to the Far East, plants on the Persian Gulf will probably play a dominant role with only supplementary supplies coming from Indonesia and Borneo. Although Japan and Korea are not likely to afford secure long-term markets for Western Hemisphere crudes, spot shipments will no doubt continue to be made to these countries from California and, later, Alberta.

Section III: Canadian Oil in Perspective

Having reviewed some of the more significant world trends, let us look a little more closely at the prospects for western Canadian oil. In doing so, we must examine several factors. Among them are;

(a) adequacy of reserves,

(b) relative costs of finding and producing oil in Canada and elsewhere, and

(c) the changing regional demand for Canadian crude.

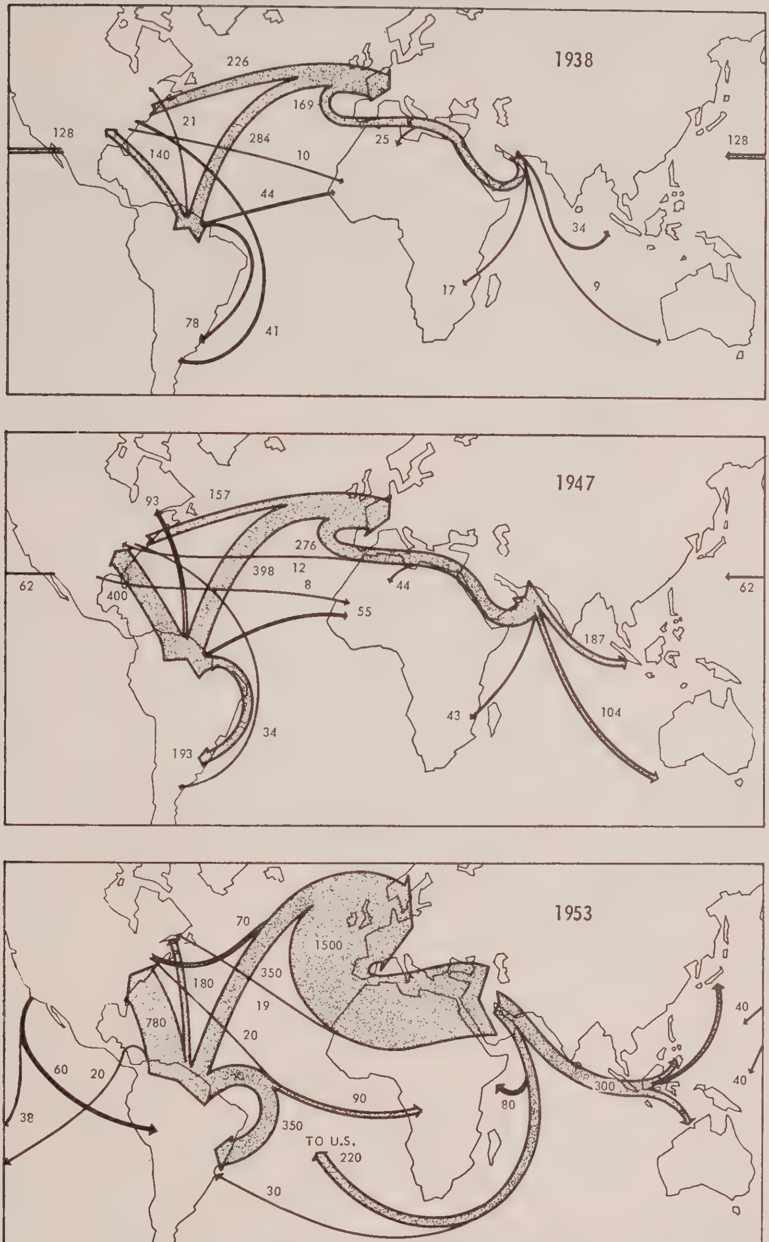
Though interrelated, they are also contingent, in no small measure, upon the extent to which Canadian production can find an outlet in adjoining areas of the United States.

Reserve and Production Prospects

First let us look at the adequacy of Canadian reserves. Historical statistics, as it turns out, are of limited use. Too little drilling has been done, and

WORLD OIL TRADE

SELECTED YEARS IN THOUSANDS OF BARRELS PER DAY



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too little of Canada's likely oil country has been mapped geologically to provide us with data on which really reliable projections can be based. Consequently, we are reduced to making comparisons with those parts of the United States where physical conditions are similar and a great deal more exploration and development has been carried out.

To anyone making an appraisal of Canada's reserve possibilities, the extent of the sedimentary area favourable to the occurrences of petroleum is a useful criterion. (See chart: Canadian Sedimentary Basins and Petroliferous Areas.) The United States Bureau of Mines informs us that, in that country, it is in the order of 1.6 million square miles. In Canada, by contrast, something like 750,000 square miles of possible oil lands have been mapped out. Produced and presently proven oil in the United States amounts to approximately 85 billion barrels. Thus, if the ratio of favourable areas is

Table 11

WORLD CRUDE OIL PRODUCTION, 1955

(in thousands of barrels)

	1955
North America	
United States	2,472,827
Canada	129,453
Mexico	89,840
Cuba	369
Total	2,692,489
South America	
Venezuela	780,450
Trinidad	24,115
Other countries	96,696
Total	901,261
Europe[a]	638,528
Asia	
Iran	116,382
Iraq	245,318
Kuwait	400,000
Saudi Arabia	349,488
Other countries	90,589
Total	1,201,777
Africa	14,196
Oceania	128,640
Grand total	5,576,891

[a]Includes Russian production of 505,000,000 bbls. in 1955.
SOURCE: *World Oil*, 1955.

Table 12

WORLD CRUDE OIL RESERVES
(millions of barrels as of mid-year, 1956)

	Reserves	% of world total in 1956
United States	30,250	15.09
Canada	3,000	1.49
Mexico	2,500	1.25
Venezuela	12,500	6.23
Other countries	1,551	0.78
Total Western Hemisphere	49,801	24.84
Russia	10,500	5.24
Iraq	15,000	7.49
Qatar	1,500	0.75
Saudi Arabia	40,000	19.95
Kuwait	50,000	24.94
Iran	26,000	12.97
Indonesia	2,300	1.15
Other countries	5,329	2.67
Total Eastern Hemisphere[a]	150,629	75.16
Total world crude oil reserves	200,430	100.00

[a]A much greater emphasis on Eastern Hemisphere oil resources was recorded by Wallace E. Pratt in February, 1956 report to the U.S. Joint Congressional Committee on Atomic Energy. He placed Middle East "actual" proved reserves at 230,000,000 barrels as of January, 1, 1955.
SOURCE: *World Oil.*

used for estimating purposes, as much as 40 billion barrels might be envisaged as the reserve potential for Canada.[14]

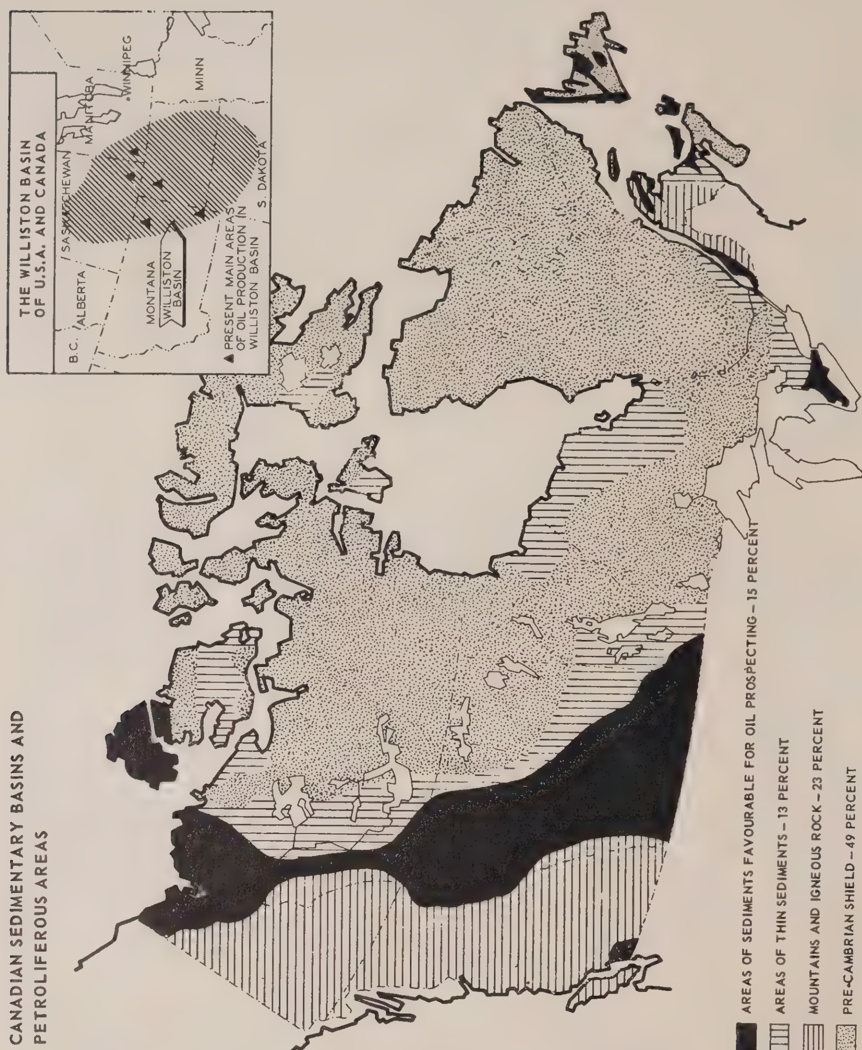
But—and this is an important proviso—the United States is far from being through as a producer of crude oil.[15] Even though some 1,500,000 wells have already been drilled, most experts agree that oil in amounts equal to that already found may yet be discovered there.[16] Yields may also be increased (in some fields more than doubled) by improved methods of recovery. With these modified United States reserve estimates in mind, a potential of, say 50 billion barrels for Canada appears possible.[17] Though academic in the extreme, such a figure is interesting. It is twice the proven

[14]Detailed geological appraisals (based on volume of sediments and oil accumulation data for the United States) have been completed for Alberta and Saskatchewan. These indicate that, for these two provinces alone, recoverable reserves may be in the order of 21 billion barrels.

[15]In reporting to the U.S. Joint Congressional Committee on Atomic Energy early in 1956, the well-known American geologist, Wallace E. Pratt, estimated that, in the next 20 years, the United States may reasonably expect to discover as much as 100 billion barrels of new oil in that country.

[16]In western Canada, by contrast, only about 15,000 wells have, so far, been completed or abandoned.

[17]No allowance is made here for the vast oil reserves known to occur in the bituminous sands of northern Alberta. These have been variously put at between 100 billion and 300 billion barrels of possible reserves.



CANADIAN SEDIMENTARY BASINS AND PETROLIFEROUS AREAS

reserves necessary to support the production estimates indicated elsewhere in this report.

General figures like these are not very reassuring in themselves. However, there is other and perhaps even more tangible evidence pointing in the same direction. Proven reserves discovered in new fields and in new pools in oil fields in Alberta in 1955 were exceeded only by those found in Texas and Louisiana. More oil was discovered in Alberta and Saskatchewan than in Oklahoma and California, the third and fourth producing states, combined. Alberta's Pembina oil field, which was under extensive development in 1955, is now believed to be one of the largest in North America.

The increase in total Canadian reserves in 1955 was equivalent to about 14% of the nation's established resources, whereas in the United States, last year's increase was equivalent to only about 2% of the proven reserves established at the end of 1954. Add to these the fact that:

(a) in 1955 one out of every five new field wildcat wells has resulted in an oil find on the Canadian prairies compared with one in nine in the United States;

(b) in 1955, newly discovered resources per exploratory well drilled in Canada were 70,000 barrels compared with 40,000 barrels in the United States;[18]

(c) in recent years, reserves discovered per foot of drilling in exploratory wells (other than outpost wells) were approximately double the reserves per foot added by similar drilling in the United States; and

(d) discoveries have now been made in many of the major horizons which have been proven productive elsewhere on this continent;

and there appears good reason to believe that Canada's western provinces may well encompass one of the most prolific oil producing regions in North America.

Once oil reserves are established, the maximum rate of withdrawal is determined by geological factors. The Maximum Efficient Rate (M.E.R.) is the one which, while permitting the greatest output, is still consistent with a maximum ultimate recovery of oil from the reservoir in question. In most pools it ranges between 3% and 9% of the recoverable reserves. Thus the ultimate life of the average oil field ranges from 12 to 33 years.

In the United States, since 1945 the annual rate of production has ranged between 6.5% and 8% of that country's proven reserves. In Canada, on the other hand, markets have not been available to an extent consistent with a maximum efficient rate of production. The output from each

[18]More correctly, newly discovered reserves in new fields and in new pools in old fields per exploratory well (other than outpost wells).

field has therefore been cut back to an intermediary level and a pro-rated allowable production based on well cost considerations and on well producing potentials is now in use. In Alberta this market allowable has been in the general range of 5% to 7% of proven reserves. Were the demand for Canadian crude to increase more rapidly than this country's production potential, the annual rate could be increased to 8% or 9% of proven reserves and still be consistent with sound conservation practice.[19]

The rapid increase in Canadian oil reserves in recent years had, by 1955, resulted in a maximum production potential approximately equal to Canada's total oil requirements. The relationship between this higher figure and that of the actual output of western Canadian oil fields indicates the extent of the shut-in capacity that has developed over the past seven or eight years.

Canadian Reserves and Production 1920-55
(in millions of barrels a year)

	1920	1930	1940	1945	1950	1955
Proven reserves[a] (December 31)	—	10	81	56	1,000	2,756
Canadian production potential[b]	—	2	9	8	57	225
Actual Canadian output	—	2	9	8	29	130
Canadian requirements[c]	18	38	58	71	134	231

[a]Crude oil and natural gas liquids available for production at year's end.
[b]Maximum Efficient Rate — *i.e.* maximum rate of production consistent with sound conservation practice.
[c]Domestic crude and products demand.

The extent to which Canada's proven reserves will increase in the future (and hence the nation's ability to produce) is, however, contingent upon a number of factors. One—already mentioned—is the amount of oil potentially available in the ground. Another is the cost of finding crude oil in this country as opposed to the outlays necessary to develop reserves elsewhere. Nor must production expenses be too far out of line with experience in the United States, Venezuela and elsewhere. Markets must also be available in sufficient volume and, at the same time, return a price at the wellhead which will more than cover prospective costs of exploration, development, and the production of additional supplies of oil. Each of these matters in turn requires a thorough-going examination before an answer can be confidently given with regard to the direction and course of future expansion in this country.

In order to establish a basis on which forward judgments as to the competitive strength of Canada's oil industry could be built it was necessary

[19]Shut-in production in Canada in 1956 was between 40% and 50% of the industry's maximum efficient rate of output.

to make a careful examination of the latest cost data, averaging, where possible, returns from a number of sources and employing definitions which were designed to ensure comparability between one country (or region) and the next. With assistance from the industry, results were obtained which suggest that producers in this country will have a strong incentive to continue their search for additional reserves over the next 20 or 30 years.

If the figures which we have been able to obtain for the years 1951 to 1954 are taken as a guide, the costs of finding and developing a barrel of oil in Canada will be well below those experienced in the United States. Exploration and development outlays in Canada have recently averaged out at around \$1.03 per barrel. Meanwhile, in the United States, they have ranged between \$1.15 and \$1.50. Due to the much shorter oil field history in this country, such upward revisions in reserves as follow from development drilling have, so far, been modest by comparison. These Canadian finding costs, were they to be viewed in a similar long-term perspective, would, in all probability be found to be below \$1 per barrel.

Production cost data have also been prepared. From 1951 to 1954 the average cost per barrel in Canada was in the vicinity of 45¢; that in the United States more like 70¢. With each passing year, however, it will cost more to produce a barrel of oil from each field. The natural forces assisting production will diminish. More pumping will be necessary, water drive and other injection practices will have to be introduced and after a time output per well will begin to fall off. With the passage of time, Canadian production costs may therefore be expected to rise to 60¢ or even 70¢ per barrel.

The following table summarizes the results of our Canadian and several American studies. (See also Appendix A).

Costs of Oil Exploration, Development and Production in Canada and U.S.
Average, 1951-54
(in dollars per barrel)

Cost category	Canada	United States	
		Low	High
Discovery and acquisition	0.62	0.73	0.68
Development	0.41	0.43	0.81
Production	0.45	0.77	0.60
Total	1.48	1.93	2.09

These are circumstances which are favourable to the search for oil. Yet, transportation costs must also be taken into account. With the important exception of the local western Canadian and United States Pacific northwest

outlets, Canadian oil has to move a greater distance to market than many of the crudes from the principal competing fields in the United States. Indeed, if the relative (roughly 2:1) advantage of ocean travel over pipeline transportation costs is also taken into account, the producers in Venezuela and the Middle East also seem to be "closer" to many of the principal oil refining centres on this continent. Expressed in terms more familiar to oil industry executives, this is the same thing as saying that the transportation penalty faced by Canadian oil is such as to reduce the net-back at the field to a level below that commonly encountered elsewhere in the Western Hemisphere.

The following table illustrates this point.

Source	Gravity	Posted field price per barrel[a]
Redwater, Alberta	35	$ U.S. 2.49
Illinois	36	2.90
California-Signal Hill	36	3.39
Mid-continent	36	2.82
Texas-East	39	2.90
-West	36	2.69
Venezuela (Oficina)	36	2.80
Middle East	34	1.95

[a]These prices are reported for June, 1956. That posted at Redwater, Alberta, was determined by the competitive price of comparable Illinois and East Texas crudes delivered at Sarnia, Ontario. Then, they could be delivered at $3.24 and $3.27 a barrel, respectively. Bearing in mind that the total transportation cost from Redwater to Sarnia was approximately 75¢, the $3.24 a barrel laid down price of Alberta oil at this point was, consequently, close to a maximum. Lacking other information, f.o.b. prices are reported for Venezuela and the Middle East.

In attempting to calculate the profitability of oil operations in Canada and elsewhere we must therefore take into account several factors. Generally speaking receipts at the wellhead are lower in this country. The disadvantage of location is more than offset by *e.g.* lower average exploration, development and production costs. Yet there is still the matter of shut-in production. Since oil found in Canada cannot be produced as rapidly as that discovered in the United States it does not offer as quick a return on investment as would similar findings on the other side of the International Boundary. The following tabulation which attempts to give each of these factors its appropriate weighing still indicates, interestingly enough, that the rate of return before taxes in Canada is already higher than that reported in the United States.

Rate of Return on Investment in Canada and The United States
Average 1951-54
(in dollars per barrel)

Item	Canada	United States High	United States Low
Receipts	2.51	3.17	2.64
Exploration, production, etc. costs	1.48[a]	2.09	1.93
Margin before taxes	1.03	1.08	0.71
Rate of return before taxes	8%[b]	7.5%	7%

[a]Based not on 42¢ production cost as has been recent experience, but on 65¢ as an expected long-term average cost of producing a barrel of oil in Canada.

[b]The rate of return before taxes as calculated here involves a discounting of future worth.

Looking ahead, one might envisage a growing shortage of North American produced oil for North American consumption. Once this reaches sizable proportions, proven reserves in Canada are unlikely to be shut-in to the same extent as they are at present. The yield on capital invested in finding oil in Canada will be further enhanced. Against this background, it seems reasonable to conclude that proven reserves in this country could well rise at a rate in excess of the markets immediately available to Canadian oil.

Regional Market Considerations

The demand for Canadian crude, both at home and in adjoining areas of the United States, is a reflection of the fact that the North American continent has, since 1947, become a net importer of petroleum. Taken together, consumption in the United States and Canada has risen more rapidly than production, and on both the Atlantic coast and in California imports from the Caribbean and the Middle East have been necessary in order to fill the ever widening gap between supply and demand.[20] (See chart: Trends in United States Petroleum Industry 1935-1954.)

Meanwhile, Canadian crude has been moving increasingly into the consuming centres in the Canadian west, southern Ontario, the United States Pacific northwest and middle west. This has permitted the older United States fields, which formerly fed refineries in these northern and western areas of the continent, to supply growing markets closer to hand. Occasional tanker shipments have also been made to northern California.

The fact that Canadian crude has been in demand has been due, in large part, to the location of its producing fields. Not only are strategic consid-

[20]United States crude oil imports rose from 236,000 bbls/day in 1946 to 782,000 bbls/day in 1955. Shut-in production in the U.S. last year was less than 15% of capacity. Shut-in capacity has existed in the U.S. because it has been more economic to import Venezuelan and Middle East crudes rather than rely exclusively on domestic production. Over the long term, however, producibility falls short of domestic demand.

erations on its side, but Alberta oil has been discovered in what was formerly a peak freight rate area. Rail shipments into the Prairie provinces from as far away as Oklahoma, Texas and Louisana, were discontinued as soon as local production became available to take their place. At first it was possible to sell western Canadian oil to these refineries at comparatively high prices. However, as output has grown and the need to compete in more distant markets has increased, wellhead returns per barrel of oil have had a tendency to decline.

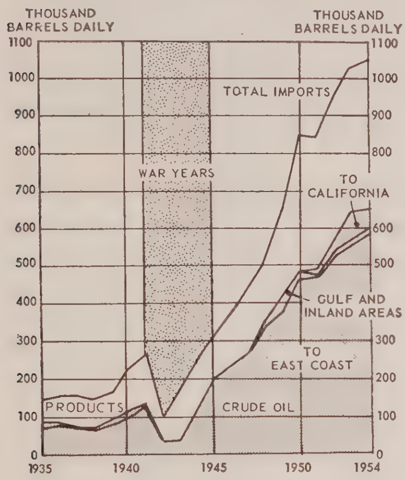
Eventually, of course, the point will be reached when a further drop in field prices brought about by the invasion of still more distant markets will more than offset the advantages inherent in an increased volume of sales. Only then will the profitable markets for western Canadian crude be fully outlined.

So far, the marketing of Alberta oil has passed through four fairly definite stages. First the problem of meeting local demand had to be overcome. This was accomplished by the building of refineries in the Edmonton area and by organizing the distribution of products by road and rail to meet the short-run needs of adjoining centres in Alberta and Saskatchewan. The second stage, beginning with the construction of the Interprovincial pipeline eastward to the Great Lakes enabled the Canadian producer of crude to compete not only on the Prairies but also at Superior, Wisconsin and at Sarnia. The third stage commenced with completion of the Trans-Mountain oil pipeline down across British Columbia to the refineries in Vancouver and those subsequently built at Ferndale and Anacortes, Washington. The fourth, if it can be called a stage, is presently under way. It consists, essentially, of a rounding out and deepening of these eastward and westward movements. Additional production, from Saskatchewan, is moving by pipeline to Minneapolis-St. Paul. Alberta oil is going on to refineries in northern Michigan and Toronto. Manitoba is now making a contribution. And, on the Pacific side, spot tanker shipments have been made out of Vancouver to refineries in the San Francisco area.

The price movements necessary, first to establish and later to retain these outlets, are interesting. As the western Canadian oil moved farther eastward it ran into competition with crudes from other sources, the laid down prices of which were correspondingly lower. The farther the Canadian oil had to move, the less attractive the price. Transportation charges, in other words, absorbed more of its sales value at destination. First wellhead prices were cut in order to capture more of the Prairie market. A further reduction was necessary in order that Alberta crude could become competitive at refineries adjoining the Great Lakes. Sarnia became the basing point with the completion of the Interprovincial Pipeline. Since then the price net-back received by the producers has continued to reflect the competitive position of Canadian oil in Southern Ontario, such subsequent variations as have occurred being dependent upon the changing value of the Canadian dollar.

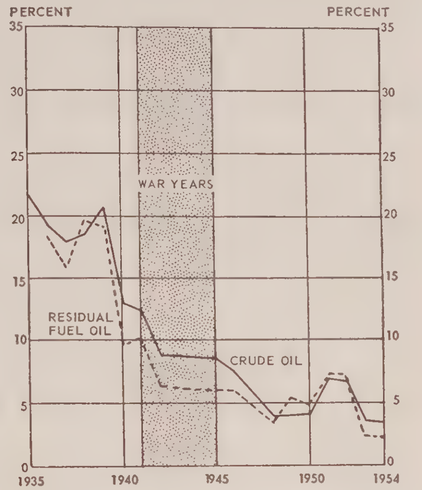
TRENDS IN UNITED STATES PETROLEUM INDUSTRY, 1935 – 1954

U.S. IMPORTS OF PETROLEUM, 1935 – 1954

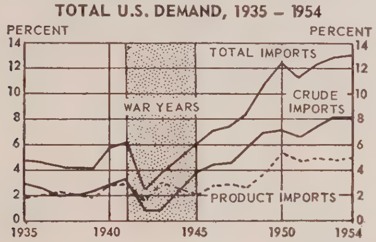


U.S. IMPORT DUTIES

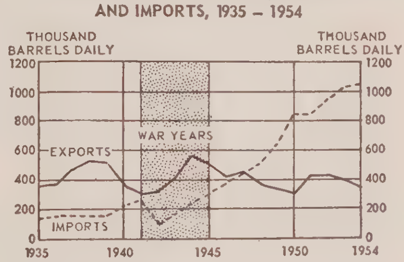
AS PERCENT OF AVERAGE U.S. CRUDE OIL PRICE AT WELL AND OF THE DELIVERED PRICE OF RESIDUAL FUEL OIL AT NEW YORK, 1935 – 1954



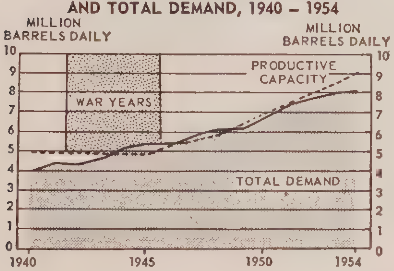
PERCENTAGE RELATION OF IMPORTS TO TOTAL U.S. DEMAND, 1935 – 1954



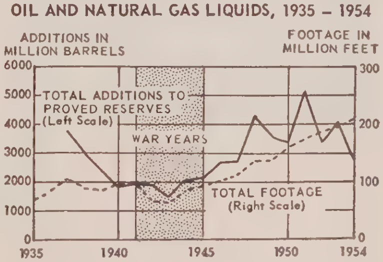
VOLUME OF U.S. PETROLEUM EXPORTS AND IMPORTS, 1935 – 1954



U.S. PRODUCTIVE CAPACITY OF CRUDE OIL AND NATURAL GAS LIQUIDS AND TOTAL DEMAND, 1940 – 1954



FOOTAGE DRILLED IN THE U.S. AND TOTAL ADDITIONS TO PROVED RESERVES OF CRUDE OIL AND NATURAL GAS LIQUIDS, 1935 – 1954



SOURCE: "A Report of the U.S. National Petroleum Council – 1955"

The situation with respect to Vancouver and adjoining west coast centres differed in one important respect. For some time, Canadian oil, with its price based on Sarnia, has been more than competitive with comparable crudes from California and the Middle East. As a result Alberta oil has been competitive with Californian and offshore crudes as far south as Portland, Oregon. The fact that it is able to hurdle the United States import tariff and capture the bulk of the Pacific northwest market is illustrated by the fact that sales to the newly built refineries in Washington State have been made without a reduction in the wellhead price of oil in western Canada.

The outlook for sales down the west coast is promising for a variety of reasons. On balance, this region is deficient in energy resources. It possesses little coal or natural gas of its own. Many of the lower cost hydro power sites will have been harnessed by 1965. Besides the oil resources of California, once sufficient to look after sizable offshore as well as western United States and Canadian demands, will do well to keep pace with the needs of the state's own refineries from now on. (See chart: Increasing Difficulties of Finding Oil in Onshore United States.)

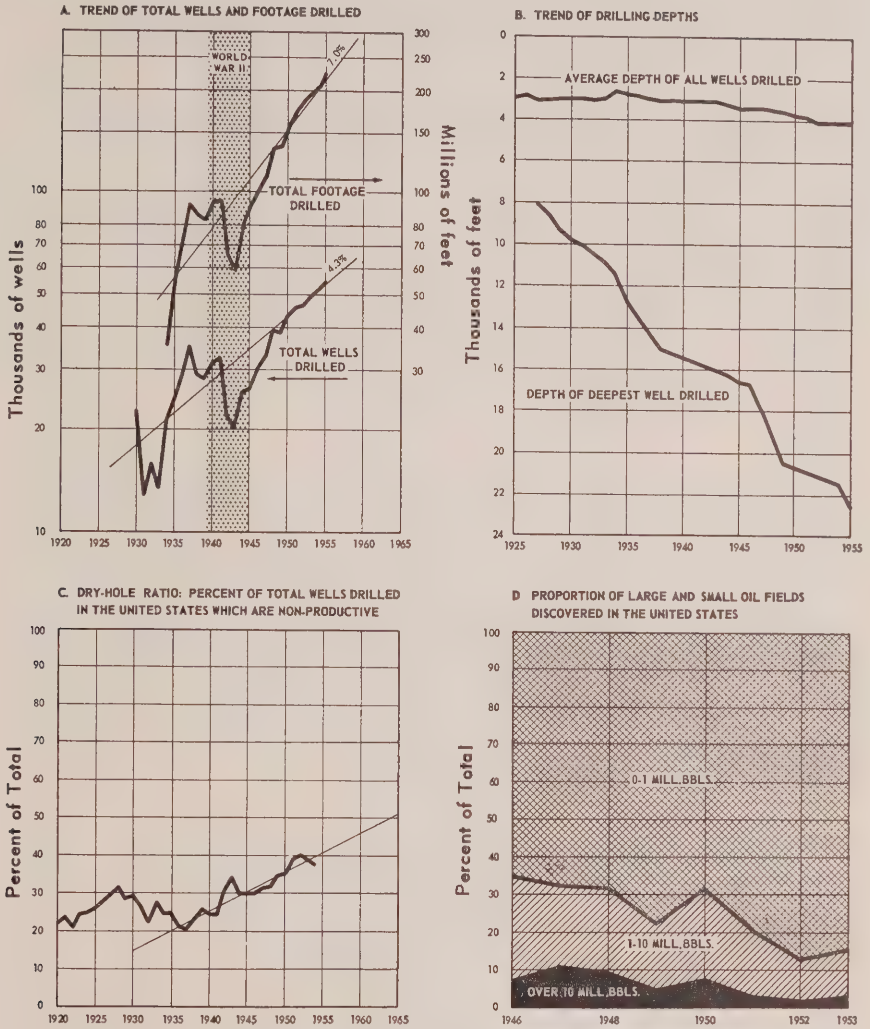
The demand for energy—at least moderately priced energy—is rapidly outrunning supply. Population and per capita income are both rising more rapidly than anywhere else on the continent. The rate of growth of industry, and particularly heavy industry, is even more phenomenal. For these reasons, and because defence considerations point to the need of developing a supplementary source of oil in the northwest, the states of Washington and Oregon together with the lower mainland of British Columbia promise to be one of the most attractive outlets—if not the most—for Alberta crude.

Other markets of comparable size are also beckoning. Several have already been tapped. However there are others in an easterly direction which also promise to take considerable quantities of Canadian oil in the years ahead.

The United States middle west, notably the states of Minnesota, Wisconsin, Michigan and Ohio already boast considerable refinery capacity. Canadian crude, as has been mentioned previously, is already being refined in Minnesota, Wisconsin and northern Michigan. A drop in price roughly equivalent to United States tariff of 10½¢ a barrel would be sufficient to put Canadian oil into the Detroit-Toledo refinery area. Were this to take place, an export outlet comparable in volume to that evolving on the west coast would be opened up to Canadian production.

As far as Canadian sales are concerned Toronto appears to mark, for the time being at least, the eastern-most limit of the Canadian oil-shed. There products made from Canadian crude are already competing with those derived from Venezuelan and Middle East oil and piped westward into southern Ontario from Montreal. Whether this will continue to be the

INCREASING DIFFICULTIES OF FINDING OIL IN ONSHORE UNITED STATES



Composite Chart of Various Data in the United States Indicating the Growing Effort Needed to Find and Produce Petroleum.

SOURCE: PETROLEUM DEPT. CHASE NATIONAL BANK, FEB. 1956

state of affairs depends, in no small measure, upon the success with which Canadian producers are able to market their supplementary crude output in the United States.

The following table gives some indication of the relative size and rates of growth of the various markets which are already supplied with, or may one day receive, substantial quantities of western Canadian oil.

Regional Consumption[a] in Thousands of Barrels a Day

Canada	1950	1955	Est. 1960	United States	1950	1955	Est. 1960
British Columbia	44	67	80	Pacific northwest	225	270	325
Prairies	76	143	169	California	660	820	1,000
Ontario	127	210	287	Mpls.-St. Paul	250	330	425
Quebec	84	150	200	Detroit-Toledo	500	650	800
Total	331	570	736	Total	1,635	2,070	2,550

[a]Of crude oil and imported products.

Collectively, these demands are well in excess of Canada's near term ability to produce crude petroleum. In Canada alone, they are equivalent to the addition every 12 months of a 40,000 barrel-a-day refinery. Adding in the growth element applicable to the Pacific northwest and Minneapolis-St. Paul refinery areas, a yearly increment of some 70,000 barrels a day is called for. Thus, even if the sales in the other potential areas of the United States are disregarded, we arrive at a prospective increase in demand comparable with western Canada's yearly rise in production potential. Since 1950, the annual growth in potential output of the Canadian oil fields has been in the vicinity of 80,000 barrels a day.

The time may well come, however, when the Canadian industry may have to look outside the confines of its present marketing area. With a 5% to 10% drop in price it could sell more into California, into the United States middle west or reach farther eastward in Canada to Montreal. In this connection, it is interesting to assess the attractiveness (price wise) of the various major markets which are now, or may one day be served from prairie fields. To begin with, one must list the price at present paid for comparable crudes laid down at the refineries in question. This, reduced to the extent of transportation charges and duties, gives a net-back to the Canadian producers which would prevail were the refinery area in question to be the basing point upon which all other offerings were made. The following table while it is illustrative only, shows that:

(a) Southern Ontario, the United States Pacific northwest and the Minneapolis-St. Paul area are the most attractive outlets for Alberta crude;

(b) that the returns from sales into the Detroit-Toledo area might be less than those resulting from basing point sales in Sarnia by an amount roughly equivalent to the U.S. tariff of 10½¢ per barrel;

(c) that, in order to obtain a share of the Montreal market, Canadian producers would have to take a cut in wellhead price of around 15¢ per barrel; and

(d) that having made the price adjustments necessary to serve all or part of the refinery needs of southern Quebec, western Canadian oil would (i) be readily salable in northern California and (ii) be close to, if not fully competitive with United States mid-continent crudes in the Chicago area.

Price per Barrel in Canadian Dollars, June 30, 1956

Destination	Price of competitive 36° crude[a]	Transportation, etc. costs from Alberta	Approx. wellhead return[b]
Sarnia	3.24	0.75	2.49
Toronto	3.30	0.81	2.49
Montreal	3.24	0.90	2.34
Ferndale, Wash.	3.39	0.70	2.69
San Francisco	3.35	0.90	2.45
Minneapolis - St. Paul	3.45	0.65	2.80
Detroit - Toledo	3.23	0.87	2.36
Chicago	3.20	0.85	2.35

[a]Competitive prices were Redwater crude value or its equivalent in other similar crudes as laid down in pipeline or large tanker lots. Tanker rates were assumed to be U.S.M.C. — 40%.

[b]Wellhead prices are arrived at by taking competitive quotations at the market area and deducting transportation cost (and duty in the case of exports). The present U.S. duty is 10½¢ on light and 5¼¢ per barrel on heavy crudes being imported into that country.

In considering the ultimate destination of Canadian oil the broad continental picture must always be kept in mind. Strategic considerations, for one thing, will continue to have an important bearing on future events. Reserves in western Canada have an inherent advantage over most offshore sources in that this oil can always be moved to North American markets over internal lines of supply. It can be expected, therefore, that the United States defence authorities will continue to discriminate in favour of Canadian oil when import allowables are being set for the northwestern, western and central market areas of the United States.

Full employment and a consequent tendency to inflation is also having a favourable effect—at least in so far as the United States tariff is concerned. Its impact on Canadian field prices has been progressively reduced as the real purchasing power of money has gone down. A useful indication of this can be obtained by dividing the duty by the average North American

wellhead price. Around 20% as late as 1938, it fell to less than 5% ten years later. Were it to be removed entirely it would add only about 4% to field prices in western Canada. Short of a major change in American tariff policy, the duty on crude oil entering that country is therefore likely to be of marginal importance during the forecast period under review.

A much more important determinant—at least in the short run—is the effect of import quotas. Currently applied on a voluntary basis by the industry itself, this type of regulation is tending to slow down, if not actually set a ceiling on sales of Canadian crude in the United States. Because sources in this country, like those in Venezuela, are given preferred treatment by the United States government authorities directing this programme, these actions are less effective than they are in respect to Eastern Hemispheric sources of supply. Yet, with an over-riding obligation to maintain their total crude oil imports at the level set in 1954, most United States companies with subsidiaries or branches in Canada have not pushed Canadian oil sales to the extent that they might otherwise have done. For the same reasons they may continue to find it politically, if not economically, desirable to draw more on their domestic reserves and leave a greater proportion of their Canadian findings in the ground. Market demand being prorated by the Alberta board, these decisions if taken would affect all producers equally.

Faced with this volume limitation, a number of Canadian independents have come out in favour of an extension of Canadian markets. Essentially, this means pushing on to Montreal. Some part of this presently 200,000 barrel a day market could be captured by something like a 7% reduction in wellhead price. As a partial solution to their problem it has its merits. Western Canadian production might, thereby, be increased by about 25% in volume and 15% to 20% in value terms.[21]

Those in opposition (and this includes most of the large internationally integrated oil companies) stress the longer view. Exploration and development costs, they say, are already rising in the United States. Faced with a persistent rise in consumption, producers there will be unable to keep pace with demand. Soon most United States refineries and later, the majority of United States producers will become more concerned with augmenting rather than finding an outlet for their own domestic production. This, they say, should happen around 1960 or, at the latest, 1965. Meanwhile, it is their view that a piecemeal development, refinery by refinery, in presently served market areas is preferable to bolder action; an action, incidentally, which exposes Canadian oil even more to competition from lower cost and better situated fields in the Caribbean and Middle East.

Once in Montreal, Canadian oil would have to compete with Venezuelan crude. The latter, moving by tanker and pipeline, could be laid down at a

[21]Any price reduction in order to gain entry into one market is also granted to all others served from the same source area.

transportation cost roughly one-half of that necessary to move Alberta oil to the refineries in southern Quebec (*i.e.* 38¢ as against approximately 90¢). Only in circumstances like the present in which tanker rates are abnormally high is it safe to assume that all—or even most—of the refinery requirements of this area could economically be supplied from Alberta.

It is difficult to say which view will prevail. Obviously, the outcome is contingent, more on future United States policy than anything else. Should Canadian oil continue to be proven up at a healthy rate and shut-in production in this country grow as a consequence of U.S. import quotas, then Canadian production will find its way in volume into Quebec. On the other hand, an early scarcity of domestically-produced oil in the United States could prevent such a development from reaching major proportions. In what follows, it has been assumed that Canadian oil, for lack of adequate export markets, will begin to move in some volume into Montreal in or about 1960. Subsequently, and especially after 1965, it was thought that market extensions in the United States would account for the major increase in Canadian crude sales.

Section IV: The Changing Pattern of Demand

Though world oil consumption has been rising for over a century, its behaviour has varied considerably, country by country and from one region to the next. There have been conditioning factors. Foremost among these has been the degree of industrialization, the reliance on transport—especially the automobile—and the abundance or relative scarcity of other sources of fuel and power. Each in turn has to be given its proper weighting before a forecast of requirements can reasonably be attempted.

The long run, worldwide upward trend in demand has been in the order of 6% per annum, *i.e.* a doubling every 12 years. In the more mature economies, like the United States, where the use of petroleum products was introduced at a comparatively early stage and where other fuels, including natural gas, have also been plentiful, the average rate (since 1920) has been more like 5.5%. Elsewhere in the free world, demand has been more erratic. Interrupted periodically by wars or altered by changing business conditions, long-term rates in the vicinity of 7% have not been uncommon. Recovering rapidly from the aftermath of World War II and stimulated by a shortage of coal, Western European needs have recently been rising at a rate in excess of 10%. Yet, even against this performance, the 12% yearly increase which has characterized Canadian consumption, postwar, makes impressive reading.

Obviously, Canada has been gaining rapidly on the United States in recent years. Per capita product usage in this country is two and a half times what it was in 1946. In the United States, by comparison, it is only about one and a half times what it was ten years ago. Not only has Canada become one of the world's largest users of petroleum products, but in per

capita terms Canadians are second only to Americans in terms of consumption. From 1930 right up until the end of World War II, the average Canadian burned only about one-half as much oil as his opposite number in the United States. By 1950, however, he was using something like two-thirds and in 1955, more like 85% as much oil as the average American.

Several reasons will be given for this recent upsurge in Canadian consumption. One is the late arrival of domestic crude production. Lagging the United States by 50 years and more, Canadians have had a good deal of ground to make up in this respect. Throughout, the major centres of Canadian consumption have been well removed from the world's main oil trade. Natural gas, too, has been more important in the United States. First used extensively in the 1930's, it has since become available in most American urban and industrial areas. Here, meanwhile, oil has had only to compete with the solid fuels—coal and wood. Finally, in the United States the contribution of all liquid fuels, because of their relative size, have begun to parellel much more closely that of energy in general. The latter, moving up more slowly than has been the past experience with oil, has already begun to impose a ceiling upon the consumption of petroleum products. Sooner or later, the same sort of thing will begin to happen in this country.

While over-all consumption in Canada has more than trebled over the past decade, this has not been true at one and the same time of all refinery products. Gasoline requirements, following roughly in line with the nation's motor vehicle population, have risen to a figure nearly three times that reported for 1946. The lighter fuel oils, mirroring the introduction of the diesel engine and affected to an even greater extent by the popularity of oil for space heating purposes, rose four times over. Relatively, the use of residual oil has lagged behind that of the other petroleum products. Yet, even in its case, demand in total has more than doubled since 1946.

The following table, which traces the growth, product by product, of Canadian consumption since 1920, indicates that the amount of oil used by the refineries themselves has also had a tendency to lag behind the nation's rising curve of oil requirements.

Canadian Consumption in Thousands of Barrels a Day

	1920	1930	1940	1950	1955	Est. 1960
Gasoline	8	47	68	137	210	282
Middle distillates[a]	9	12	20	87	192	269
Heavy fuel oil	11	27	40	80	120	131
Lubricating oil	2	3	4	6	9	9
All other products[b]	6	6	12	31	66	93
Refinery consumption	3	9	14	26	36	54
Total	39	104	158	367	633	838

[a]Domestic heating oils (*i.e.*, light fuel oil and stove oil) and diesel fuel oil.
[b]Asphalt, greases, waxes, petroleum coke, etc.

A breakdown by principal end-use makes even more interesting reading. It shows that, over the past quarter century, the transportation sector has been taking a progressively smaller percentage of all the oil consumed in this country. At that, highway transport still utilizes well over one-third and the railways and shipping, together, close to 10% of the total. Residential and commercial space heating, meanwhile, has emerged as one of the, if not *the* major determinant of refinery schedules and construction. Constituting some 12% of the total market for all products at the end of World War II, it accounted for close to 25% in 1955. By comparison, the other major use categories have remained relatively stable. Manufacturing has just about held its own with 15%. Agriculture and other primary industries, together, have continually accounted for around 4% of total Canadian crude oil and product sales.

The rate of growth of demand for petroleum products varied considerably in the five main marketing regions of Canada during the period 1946-55. The following tabulation showing principal fuel consumption in each marketing region for the years 1946, 1950 and 1955 illustrates this varying rate of growth, and also the importance of Ontario and Quebec in the Canadian fuels economy.

Consumption of Motor Gasoline
(millions of barrels)

	1946	1950	1955
Maritimes	2.5	4.0	5.9
Quebec	5.9	9.2	14.6
Ontario	12.4	18.7	29.1
Prairies and N.W.T.	9.3	13.5	19.4
British Columbia	2.7	4.1	6.6

Consumption of Light Fuel Oils[a]
(millions of barrels)

	1946	1950	1955
Maritimes	1.4	2.2	4.8
Quebec	4.4	7.3	16.5
Ontario	4.3	9.2	21.9
Prairies and N.W.T.	1.2	0.9	5.3
British Columbia	1.8	2.1	5.1

[a]Kerosene, stove oil, furnace oil, other light fuel oil.

Consumption of Heavy Fuel Oil
(millions of barrels)

	1946	1950	1955
Maritimes	2.3	3.1	5.4
Quebec	4.0	7.3	13.6
Ontario	4.1	4.8	9.1
Prairies and N.W.T.	2.1	5.7	8.2
British Columbia	4.7	6.1	6.8

These changing regional requirements have also had an important bearing on Canadian self-sufficiency in respect to oil.

Quantity in Thousands of Barrels a Day

	1920	1930	1940	1945	1950	1955
Canadian production	1	4	23	23	80	355
Imports (a) crude	30	79	117	159	224	238
(b) products	8	22	19	18	85	104
Exports (a) crude	—	—	—	—	—	46
(b) products	—	2	1	6	1	3
Domestic supply	39	104	158	194	388	648
Percent self-sufficient	2½	4	15	12	21	55

Over the years, several foreign sources have supplied the Canadian refineries with petroleum brought in from outside the country. During the 1920's and early 1930's, most of this oil—both crude and products—came from the United States. The first shipments from South America began in volume just prior to World War II. First Colombia and Trinidad and, later, Venezuela, became the major source of crude oil supply to the Maritimes and much of Central Canada. This tendency towards a greater dependency on fields outside North America was accelerated by the war. Defence priorities in the United States dictated that a greater proportion of that country's own production should be used at home. Canada was forced to turn elsewhere for much of its crude. Only British Columbia and, to a much smaller extent, Southern Ontario, continued to draw on American fields after 1945.

The following table indicates the relative importance and regional shifts as to the source of supply of crude oil entering Canadian refineries since 1930.

Quantity in Thousands of Barrels a Day

Year	Canada	U.S.	South America Venezuela	South America Other[a]	Middle East	Total supply
1920	1	22	—	8	—	31
1930	4	54	10	15	—	83
1940	23	80	9	28	—	140
1945	21	89	44	26	—	180
1950	72	86	82	7	49	296
1955	292	20	181	10	27	530

[a]Colombia and Trinidad.

Several other characteristics in the postwar period are worth noting. Not only have Canadian requirements been increasing rapidly, but also shipments of oil from Middle East fields have become an important factor in the Canadian fuel economy. Crude imports from Venezuela are still rising while receipts from the United States are now confined to serving of comparatively modest demands in the Sarnia refinery area of Southern Ontario.

This is not the case with manufactured oils. Imports of refined products from United States sources have continued to enter Canada at a fairly steady rate during the last few years. These are being consumed largely in Newfoundland, New Brunswick and the other Maritime Provinces, eastern Quebec and the west coast of British Columbia.

Down through the years, there has been a tendency for refinery construction to lag behind the nation's mounting products requirements. This has been true particularly in the late 1920's and since 1945. In the decade immediately after World War I, the country's motor gasoline requirements far outstripped domestic production. More recently, exceptionally heavy demands for house heating and diesel oils have had to be met by increased shipments from refineries in the United States and the Caribbean area.

The following table shows the relative importance of Canadian production and imports of refined products from 1920 up until the present time.

Quantity in Thousands of Barrels a Day

	1920	1930	1940	1945	1950	1955
Domestic production	22	83	127	164	278	535
Imports	16	23	18	16	75	104
Imports as % of supply	42	22	12	9	21	16

Section V: Supply-Demand Trends 1955-80

From what has been said already, it is apparent that:

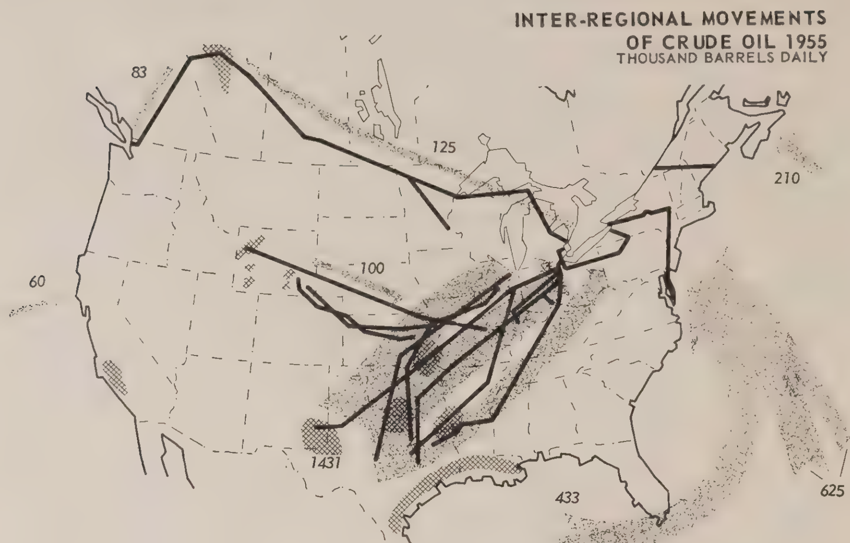
(1) Canada's requirements for petroleum products will go on increasing over the period under review;

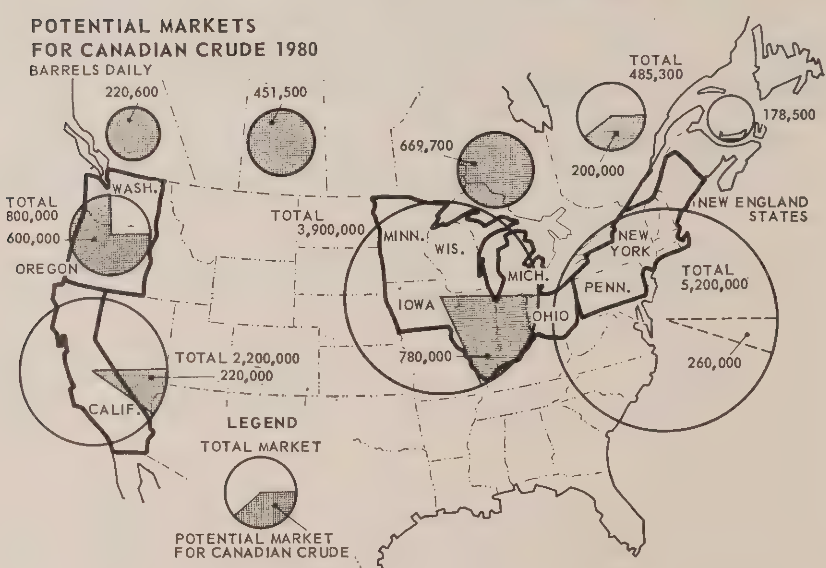
(2) fields in western Canada can be counted upon to meet a substantial part of these needs; and that

(3) in order to maximize the return on Canadian production, a growing proportion of this country's output of crude petroleum will have to be exported to adjoining areas in the United States in the years between now and 1980.

Imports, nevertheless, will be necessary. These will continue, perhaps, in increasing volume to enter refineries in the Maritimes and southern Quebec. It still remains to be seen whether, on balance, Canadian exports will exceed these input flows by a substantial margin. This section, relating to the supply-demand prospects of the Canadian oil industry over the quarter century from 1955 to 1980, has been written with a view to shedding further light on this important aspect of Canada's international trade. (See chart: Inter-Regional Movements of Crude Oil 1955, Potential Markets for Canadian Crude 1980.)

It is apparent that Canada's oil producing potential is considerable.


INTER-REGIONAL MOVEMENTS
OF CRUDE OIL 1955
THOUSAND BARRELS DAILY
83
125
210
100
60
1431
433
625


POTENTIAL MARKETS
FOR CANADIAN CRUDE 1980
BARRELS DAILY
220,600
451,500
TOTAL
485,300
178,500
669,700
200,000
WASH.
TOTAL
800,000
600,000
OREGON
TOTAL
3,900,000
MINN.
WIS.
MICH.
IOWA
OHIO
780,000
NEW ENGLAND
STATES
NEW
YORK
PENN.
TOTAL
5,200,000
260,000
TOTAL 2,200,000
220,000
CALIF.
LEGEND
TOTAL MARKET
POTENTIAL MARKET
FOR CANADIAN CRUDE

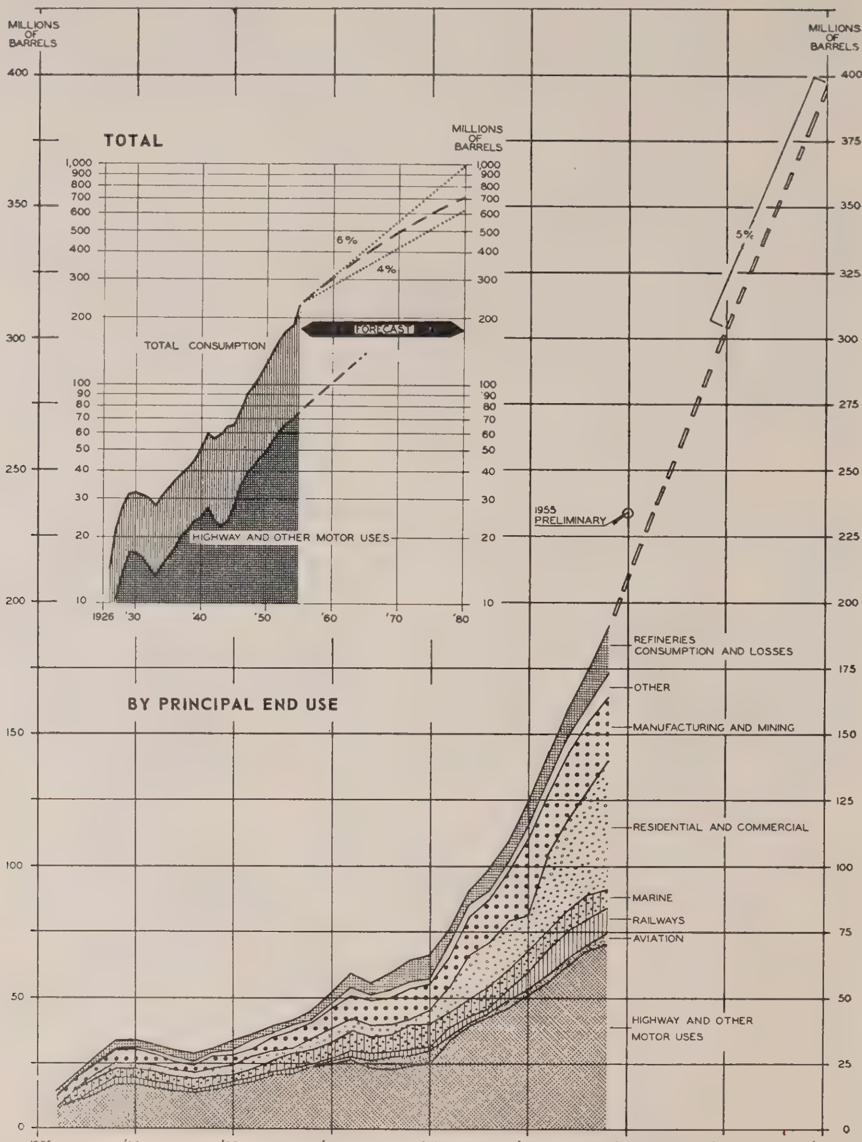
Costs of exploration and development, furthermore, will continue to compare favourably with those encountered elsewhere in North America. Yet, before this productive capacity can be translated into proven reserves, substantial investments must be made. An incentive in the form of expanding markets—markets which also offer a net-back to producers at least as great as that encountered elsewhere—is imperative. Continuity of operations is also important. Effective demand, in other words, is likely to be the main determinant of this industry's growth over the next 20 to 30 years.

While a lack of adequate markets might not be a serious deterrent in the short run, this is not likely to be true over a period of years. In other words, a levelling off of domestic and export sales may not be followed immediately by a commensurate decline in drilling activities. However, beyond 1960, and most certainly in the late 1960's and during the 1970's, the rate at which fresh reserves are proven up in this country will depend, more and more, upon the establishment of adequate outlets for Canadian crude. A thorough-going market analysis is, therefore, fundamental to any assessment of the long-term prospects, not only of the refining and marketing, but also of the production and transportation sectors of this important industry.

Various methods can be used for forecasting the effective demand for Canadian crude. (See chart: Consumption of Petroleum Products in Canada 1926-1980.) Historical rates can be used as a guide. Projections of demand by individual use categories or by major refinery products can be employed. Though less reliable, an attempt can also be made to assess and add up regional petroleum requirements and, from time to time, international comparisons can be employed as a check on the results which have been obtained. In the interests of simplicity an average of the results obtained from the foregoing analysis has been selected in order to portray the most likely course of events.

The first task was to choose a "reasonable" annual percentage rate of growth. Applied to current consumption, it would give some indication of future aggregate requirements. Starting at 6% and falling progressively to 4%, such a series was assumed to reflect the likely course of demand over the next 25 years. Six per cent was believed likely to apply to the period from 1955 to 1960. Though well below the 12% figure recorded for the postwar years, it can be defended on several grounds: namely, that natural gas will begin to enter the eastern Canadian space heating and industrial fuel markets in 1959; that oil has already displaced coal in many of the applications in which liquid fuels can be employed to greatest advantage; and, finally, that the oil industry itself regards a 6% rate as optimistic for this five-year interval. A 5% yearly rate was selected for the decade between 1960 and 1970. It was chosen because this has been the experience in the United States at a time when the sale of natural gas and its various by-products was also vying actively with oil in a number of the latter's major markets. After 1970, an average 4% rate, hinging on the belief that

CONSUMPTION OF PETROLEUM PRODUCTS IN CANADA 1926–1980



oil's share of the total Canadian energy market—already around 50%—is unlikely to increase thereafter. In other words, the demand for petroleum products may well parallel that of all other forms of fuel and power. As discussed elsewhere, 4% might well approximate the growth of Canada's over-all energy requirements 20 to 30 years from now.

On the average and taken over the entire period from 1955 to 1980, this is equivalent of a 4.5% rate. In other words Canadian requirements may, on these assumptions, approach a two million barrel a day rate by 1980 (or approximately three times their 1955 rate 25 years from now.)

All other forecast methods gave lower results. An analysis of demand by major end use, for example, indicated a total Canadian requirement in the vicinity of 1,850,000 barrels a day 25 years hence. A listing of the main reasons given for this progressive dropping off in requirements includes:

(a) a proportionate decline, after 1960, in the amount of oil used for space heating;

(b) completion of the railways' dieselization programme in the early 1960's. This, plus the expected decline in the railway's share of the total transportation market, points to a smaller proportion of refinery output being devoted to this purpose;

(c) in manufacturing, oil has been gaining rapidly on coal. Only in a few areas has it had to compete with natural gas, propane, etc. From now on, it will find coal more difficult to displace. This is true particularly where energy is required in bulk and coal can be obtained from low cost sources in the United States. At the same time, its opportunities for growth will be restricted by offerings of natural gas, especially in British Columbia, Manitoba, Ontario and Quebec;

(d) oil for the generation of electric power will be limited substantially to the Atlantic region; and

(e) most other applications—though growing—are likely to be modest compared with total crude oil requirements. This applies to aviation use and the production of petrochemicals. That used by shipping may become stabilized relative to total economic activity. Propane may offer a certain amount of competition in agriculture and the amount of oil consumed by the industry itself may move more or less in line with its over-all total output of crude and products.

A third method recognizes the demand for gasoline as a major determinant of refinery construction and, hence, of other product sales. In this instance, it has been necessary to forecast both motor vehicle population and per vehicle requirements in 1965 and 1980. Subsequently modified to allow for a moderate rise in percentage gasoline yield from crude, this

approach resulted in an estimated demand for petroleum products in Canada in the vicinity of 1,825,000 barrels a day 25 years hence.

The estimate of passenger car registrations was made by assuming that this was a function of population, income and vehicle obsolescence. The same approach was used in respect to farm tractors except that the number of farms was substituted for population. The 1980 registration of farm tractors, incidentally, implies almost complete saturation. Increases in numbers of commercial vehicles were related to over-all expectations as to business activity and, again, of vehicle obsolescence. The following results were obtained: registrations at year end 1980—passenger cars, 9,120,000; commercial vehicles, 2,960,000; farm tractors, 940,000.

Per vehicle usage had also to be assessed. Here it was assumed that there would be no major improvement in efficiencies of utilization between now and 1980. In other words, efficiency gained in the commercial sector due to the more extensive use of diesel and, possibly, free-piston type engines of larger sizes will be substantially offset by diseconomies in the privately-owned passenger car field. Past figures on per vehicle consumption were, therefore, employed, careful attention being paid to the effects of changes in the ratio of passenger cars to commercial vehicles. In total, the growing relative importance of the privately-owned automobile considered, and allowing for the progressively greater number of automobiles, consumption per vehicle was expected to be up by roughly 10%. Total gasoline demand, on this basis, would rise by about 350% between now and 1980.

Following this line of reasoning, the trend in average refinery gasoline yields had also to be established. In Canada, the quantity of gasoline extracted from a barrel of crude oil has been falling. It dropped from 40% in 1948 to around 37% in 1955. In the United States, where space heating is less of a factor, where natural gas and its by-products have intercepted a number of demands which would otherwise have accrued to the lighter fuel oils, and where per capita vehicle ownership is higher, gasoline yields have consistently been higher. In the order of 42%, they are actually on the increase. Industry projections to 1965 see gasoline output as a percentage of crude oil consumption reaching 45%. For purposes of this report, a turnaround in Canadian refinery practice has, consequently, been anticipated. In order to derive figures for total product demand, refinery gasoline yields of 40% and 42% were employed for the years 1965 and 1980 respectively.

A fourth approach involves a summation of regional demands. As reported elsewhere in this study (see Chapter 13), it resulted in a provisional estimate in the vincinity of 1,750,000 barrels a day for 1980.

Having approached our problem from several different directions, we now find ourselves with a high of 2 million barrels a day, a low of 1,750,000

barrels a day, and several intermediate forecasts to choose from. Rather than select any one of them, an average has been struck. This indicates a total Canadian crude and product requirement in 1965 of 1 million barrels, and an average of 1,900,000 barrels a day in 1980.

In order to see what this means to Canadian refinery throughout, some judgment must be applied to the future course of product imports. In recent years, they have accounted for between 15% and 20% of total Canadian consumption. The 1955 figure was approximately 16%. The majority of oil industry executives who were interviewed on this point believe that, over the next decade, the ratio between Canadian produced products and imports would be in the order of 7:1.

After 1965, some increase in Canada's self-sufficiency may occur. With a progressive moderation in total demand, refinery construction may eventually catch up and, hence, be better adopted to the meeting of Canadian requirements. An invasion of natural gas into the space heating field could have a moderating effect on the production of middle distillates, particularly in southern Ontario. With the advent of the gas turbine, aviation gasoline requirements—most of them presently supplied from the United States—will subside. As regional markets reach a size sufficient to support the output of a well integrated refinery, fewer specialty items will have to be purchased elsewhere. On balance, it was thought that developments of this kind would perhaps more than offset an appreciable rise in imports of residual oil for power generating and other industrial purposes. In the following calculations, it has, therefore, been assumed that refineries in other countries will supply about 15% of Canada's total oil needs in 1965 and around 12% in 1980.

Allowing for an import contribution of this order of magnitude leads to a refinery crude oil requirement in Canada of some 850,000 barrels a day in 1965 and approximately 1,675,000 barrels a day in 1980. Next, in order to quantify the demand for Canadian crude, an appraisal of the regional prospects for refinery construction was carried out. The results of this analysis indicated that crude from western Canada might supply as much as 85% of the nation's total refinery requirements 25 years from now.[22] In volume terms, this amounts to some 710,000 barrels a day ten years from now and around 1,400,000 barrels a day 25 years hence.

In order to determine the total demand for Canadian crude, exports must also be included. In looking ahead to 1980, three major United States

[22]In order to complete these calculations, several assumptions had to be made. They were: (a) all refineries west of Montreal would operate entirely on Canadian crude after 1960; (b) a further 100,000 barrels per day of Canadian crude would be processed by Quebec refineries in 1965, 200,000 barrels per day in 1980; (c) Canadian demands over and above these amounts in Quebec and in the Atlantic region would be supplied from foreign sources—principally from the Caribbean area; (d) 75% of all Canadian product imports will enter the Maritimes, Newfoundland and Quebec.

market areas were considered to be within the orbit of western Canadian oil. These were the United States Pacific Northwest, northern California, and several major refining centres bordering on the Great Lakes.

On the West Coast, the present Washington-Oregon market for Canadian crude promises to show considerable growth. Based on a 4.5% annual rate of growth to 1980, the total market for petroleum in that area would be at least 800,000 barrels per day. Assuming an approximate 75% share for Canadian crude, the market outlook for these two states would amount to some 600,000 barrels per day at the end of our forecast period.

In California, the total state market for petroleum in 1980, assuming a lesser 4.25% annual rate of growth, would be about 2,200,000 barrels per day. If Canadian crude should capture 10% of this market, a daily outlet for 220,000 barrels would be provided. Considering the magnitude of this state market in relation to total potential supply from the United States west coast, a 15% share for Canadian crude might even be judged to be on the conservative side.

In the north-central part of the United States, an encouraging market situation for Canadian crude has already developed in Minnesota, Wisconsin, and Michigan. Adding to these state markets, those of Illinois, Indiana, and Iowa and projecting a 20% share in the total market of this group of states by 1980, we find here another sizable market for Prairie oil. By 1980, this group of states should, at a 4% annual growth rate, have a total market of 3,900,000 barrels per day. At 20%, the Canadian share would amount to some 780,000 barrels.[23]

In total, these projections indicate a possible market for Canadian crude oil in the United States by 1980 for some 1,600,000 barrels per day. Were it to be realized, it would represent only about 20% of the projected 25th year demand of refineries on the West Coast and in the midwestern states. Bearing in mind the rapid reserve build-up which is currently taking place in Canada and the strain which a continuing growth in United States requirements may place upon that country's resources after 1965, some such proportion as this might well be attained. Even more important arithmetically is the assumed rate of growth in demand. Were this to be 4.5% or even 5% per annum in the majority of these export areas, western Canada's contribution would appear to be smaller still.[24]

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[23]Some movement of Canadian crude even farther east might be anticipated. The New York-Pennsylvania-New England States' market will total some 5,200,000 barrels a day in 1980 if growth continues at the nominal 4% rate. Even a 5% share in this total market would presume daily shipments of 260,000 barrels from Canada. No provisions for this has been made in this exercise.

[24]For example, if a continuing 5% per annum rate of increase in demand in these potential export areas were to be used, a Canadian sale of 1,600,000 barrels a day would serve only about 15% of the total crude and product demand in these regions in 1980.

As we have seen, the potential market for western Canadian crude in Canada may approach 1,400,000 barrels a day in 1980. Assuming the oil is there, export outlets the equivalent of 1,600,000 barrels a day may also be available to adjoining areas of the United States. For this reason, a total demand for Canadian crude of three million barrels a day has been chosen as representative of the likely state of affairs 20 to 30 years from now.

Supply estimates must, of necessity, be even more tentative in nature. Physically, there appears to be no reason why Canada cannot become a substantial producer of crude petroleum. The nation's favourable petroliferous areas are extensive. Besides, oil has been found in many of the geological horizons which have been proven productive elsewhere on the North American continent. Costs of exploration, development and production are also below the American average. Due to the fact that the search for oil has only recently commenced in this country and that much of the Canadian oil will come from relatively young fields, this may continue to be the case for several decades.

Net-back prices to Canadian producers, meanwhile, may remain relatively stable. Further economies in transmission will help to offset the need to sell over greater distances. Assuming a limitation of overseas imports, market prices, particularly in the United States, may rise. The amount of oil shut-in for lack of outlets may also be reduced in time. Effectively this would raise the rate of return on investment. Hence, it, too, should provide a further stimulus to the search for additional reserves in this country. What the results will be is difficult if not impossible to forecast. Yet most competent observers, inside the industry and outside, can see that the servicing of an annual demand in the vicinity of three million barrels a day is possible. Some would even venture to say that, given continuity in demand and some appreciation in price, even larger quantities of oil would be found in this country.

After careful study, three possibilities have been envisaged. Under Case A, we have assumed that the reserve position will be sufficient to maintain an annual output of 2.5 million barrels a day in 1980. In this case, export markets would be confined to the United States Pacific Northwest, Middle West, and north central states. In establishing Case B (which envisages an annual output of three million barrels a day), Canadian oil is also assumed to be entering the San Francisco and the Detroit-Toledo areas in substantial volume 25 years from now. Case C, which is consistent with an annual output of some 3.5 million barrels of Canadian crude a day is even more optimistic. Its realization implies two things: a still more favourable rate of discovery in Canada, on the one hand, and a greater than 4% per annum rate of growth in demand for petroleum products in the aforementioned market areas in the United States.

These expectations are further outlined in the accompanying chart, entitled Crude Oil Supply-Demand Trends in Canada 1950-1980. In summary, it shows that:

(1) while Canada's over-all energy requirements may rise about 2.8-fold the demand in this country for crude petroleum may treble between 1955 and 1980;

(2) the total demand for Canadian crude may multiply by between eight and ten times with production reaching a level of three million barrels a day 25 years from now. Its magnitude, however, will be dependent more on supply than on market considerations;

(3) crude oil reserves of around 25 billion barrels of oil might be found. Of this, 12 billion might have been produced by 1980, and some 13 billion barrels could therefore be considered as reserves in sight in that year;

(4) shut-in production, on these assumptions, would fall from its present 45% of the maximum economic rate of production to around 10% in 1980; and

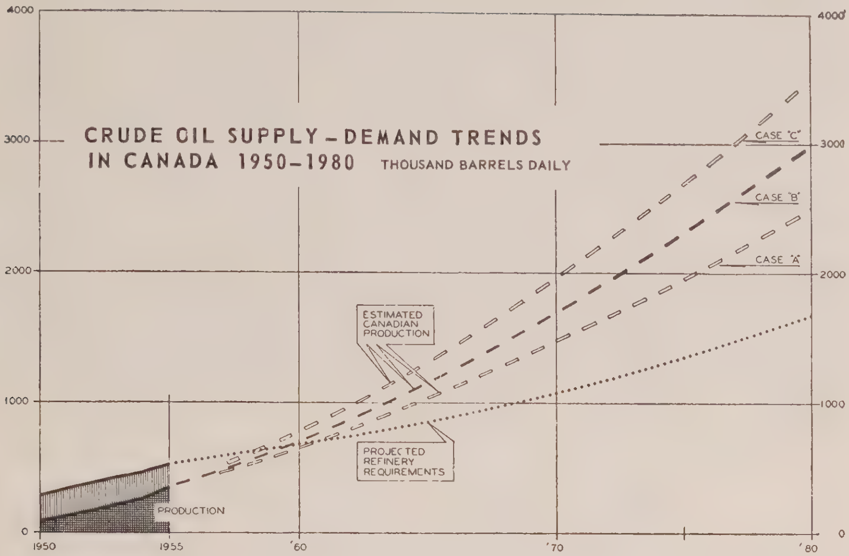
(5) Canadian exports of crude oil will exceed imports by a margin of 6:1 or 7:1, 20 or 30 years from now.

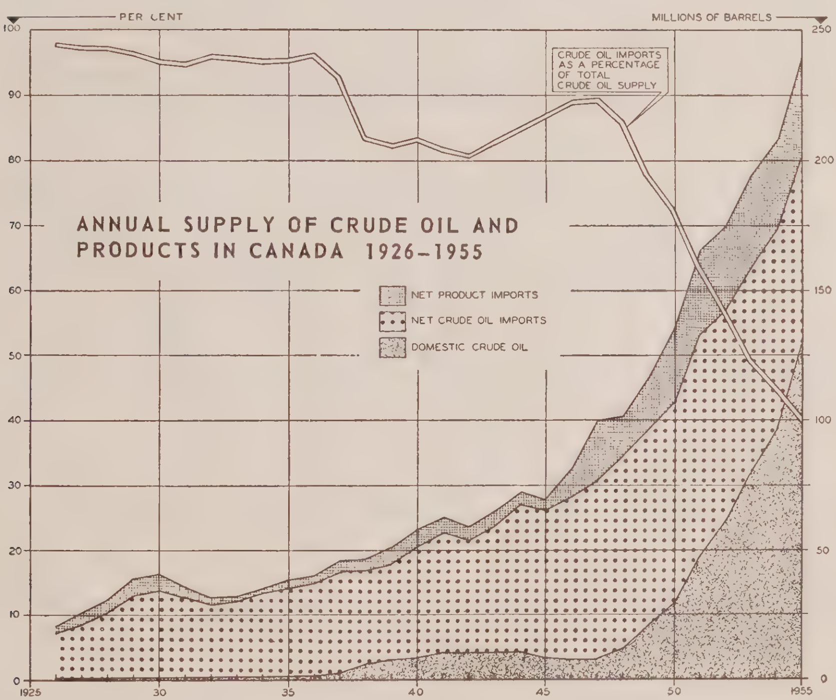
Section VI: The Long-Term Development Programme

Investment Aspects

In the eight-year interval since the discovery of the Leduc field early in 1947, the oil industry has invested over $3,000 million in its efforts to find, produce, transport and process its products for market. These outlays, furthermore, have followed a rising trend. In 1946, for instance, expenditures on exploration and development expenses totalled only $15 million. By 1950, they had reached $150 million, and in 1955 they were known to have exceeded $400 million. As a rough measure of the interest which the large international and smaller Canadian companies have been taking in the opportunities offered by this resource, this record is impressive indeed.

Other measures can, of course, be employed. The amount of land under reservation or lease has risen tenfold. Acreage committed in this way now includes most of the likely oil country in British Columbia, Alberta, west central and southern Saskatchewan and southwest Manitoba. Fewer than 20 geophysical crews were at work in 1946. Over the past five years their number has ranged between 160 and 190. The total number of wells drilled in western Canada has also shot upward. In the order of 3,000 in 1955 they marked an approximate ninefold increase over the numbers being run in eight years previously.


CRUDE OIL SUPPLY – DEMAND TRENDS
IN CANADA 1950–1980
THOUSAND BARRELS DAILY
CASE "C"
CASE "B"
CASE "A"
ESTIMATED CANADIAN PRODUCTION
PROJECTED REFINERY REQUIREMENTS
PRODUCTION
4000
3000
2000
1000
0
1950
1955
'60
'70
'80


PER CENT
MILLIONS OF BARRELS
CRUDE OIL IMPORTS AS A PERCENTAGE OF TOTAL CRUDE OIL SUPPLY
ANNUAL SUPPLY OF CRUDE OIL AND
PRODUCTS IN CANADA 1926–1955
NET PRODUCT IMPORTS
NET CRUDE OIL IMPORTS
DOMESTIC CRUDE OIL
100
90
80
70
60
50
40
30
20
10
0
250
200
150
100
50
0
1925
30
35
40
45
50
1955

Expenditures on pipeline and other transportation facilities have been more intermittent in nature. They rose sharply in 1950 and 1952 when major new transmission links were being forged, only to drop back again a year or so later. Even here the progressive looping (in order to increase throughput) has resulted in a greater degree of continuity in investment than was formerly expected to be the case. Each year since 1952 the industry has spent no less than $65 million on this phase of its expansion.

Meanwhile, new refinery capacity is continually being built. Outlays designed to produce both a greater volume and a wider variety of petroleum products have edged persistently upward. In 1955 alone the cost of erecting new processing plants was in the vicinity of $100 million. The following table indicates in a general way both these changing magnitudes and the shifting regional emphasis of this more domestically market oriented programme.

Year-end Capacity in Thousands of Barrels of Crude Oil per Day

Year	British Columbia	Prairie Provinces	Ontario	Quebec	Atlantic Region	Total
1945	21	41	75	59	34	230
1950	29	88	75	143	22	357
1955[a]	67	174	149	210	18	618

[a]At the end of 1956, there were 24 companies operating 43 oil refineries in Canada with capacities ranging from 300 barrels per day to 80,000 barrels per day.

In order to make up ground lost during World War II, the Canadian oil refinery operators immediately embarked upon an extensive programme both of expansion and modernization. During the past decade, as we have seen, they have succeeded in raising the rated capacity of their plant threefold. In addition, considerable emphasis has been placed on the installation of catalytic cracking and reforming units. This has been done in order that a larger proportion of the nation's high quality gasoline and distillate demands could be produced from the crude oil available.

Initially, much of the new capacity was installed in the Prairie Provinces and in Montreal. Somewhat later, with the arrival of Alberta oil in southern Ontario and in Vancouver, refineries in the Sarnia and Toronto areas and on the West Coast began to receive more attention. Latterly, additional capacity appears to have been added more or less uniformly across the country with substantial additions or complete rebuilding programmes being initiated in most of the major centres from Halifax to Vancouver, B.C.

The outlook, in so far as new investment in this phase of the industry's activities is concerned, is reassuring. As long as Canadian consumption of petroleum products continues to rise at an annual rate in the vicinity of 5% the industry will have to continue to invest anywhere between $75

and $100 million a year in order to maintain its position relative to imports in the Canadian market.

Outlays in respect to marketing have, similarly, continued to mount. Now in the order of $50 million annually, they too, may level off when greater competition is felt from natural gas. However, if the relative size and continuity which has been evident in the later phase of the industry's growth in the United States can be taken as any guide, marketing like refinery investment will remain one of the most active sectors of expenditure in the Canadian economy.

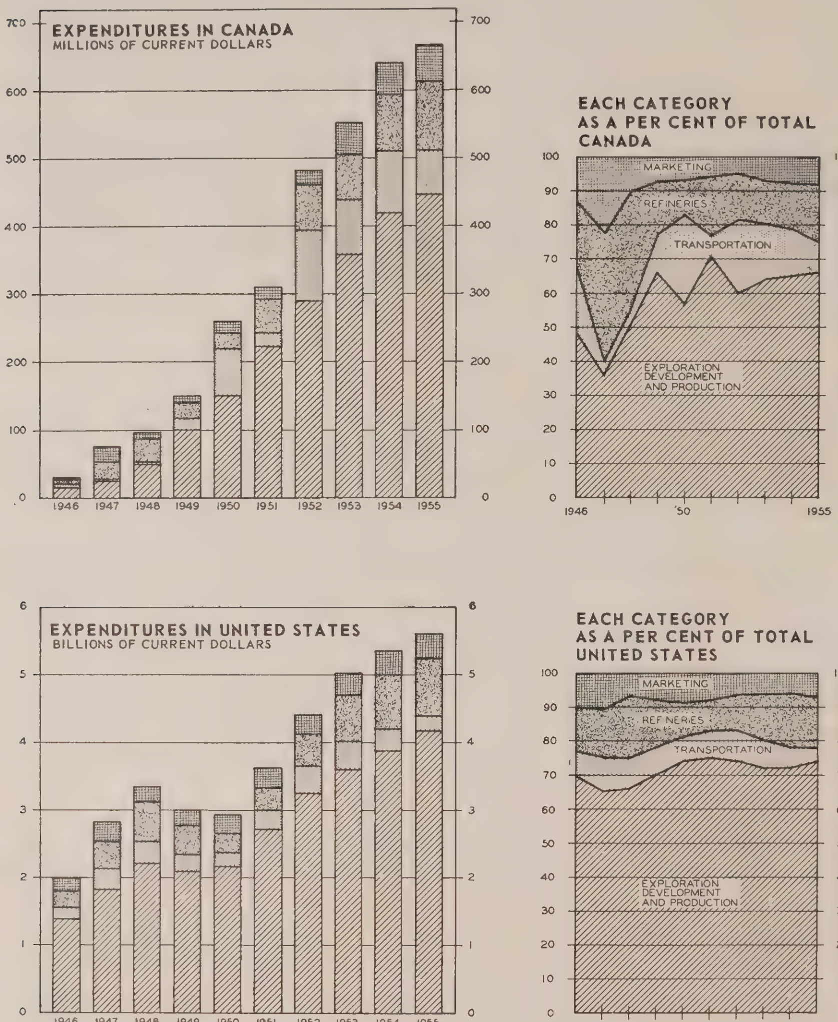
Table 13 shows somewhat greater percentage expenditures in transportation in Canada than in the United States with corresponding smaller expenditures in exploration, development and production in Canada. Percentage expenditures in refineries and marketing are similar in both countries. (See chart: Investment in the Petroleum Industry Canada and United States 1946-1955.)

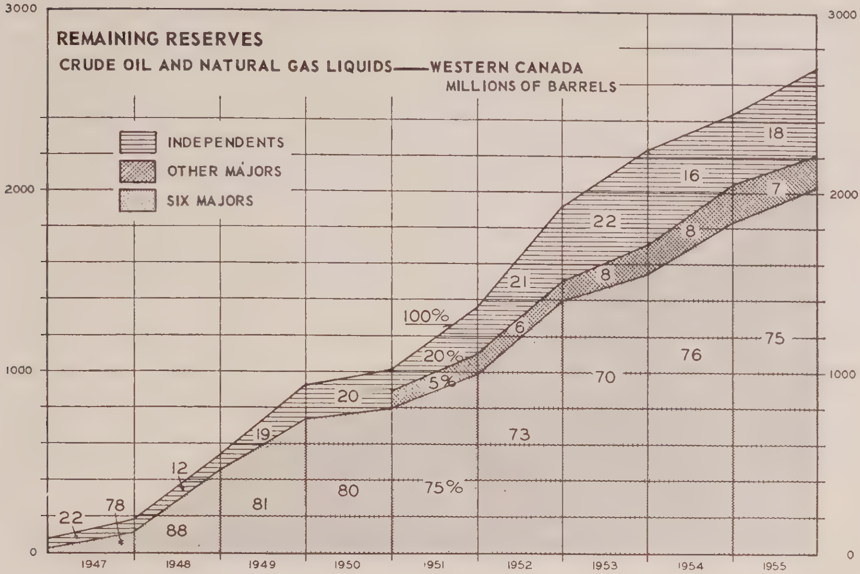
Structure of the Canadian Industry

The Canadian oil industry consists mainly of large firms with important international connections—a state of affairs which is also true of petroleum operations in most other producing countries. Here 70% of the land under reservation or lease and close to 80% of the presently proven oil reserves in the four western provinces are known to be in the hands of corporations owned and controlled in the United States. Canadian independents, several of which are partly integrated in the sense that they engage in several phases of the industry's activities, hold 10% to 15% of the acreage and about 12% of the known oil reserves of western Canada. The balance is in the hands of other foreign investors, principally corporations headquartered in the United Kingdom, Belgium, Holland and France. (See chart: Remaining Reserves, Crude Oil and Natural Gas Liquids—Western Canada.)

Since the late 1940's, Canada has passed through a major investment boom. A large number of small companies were launched. Many of these have since disappeared, having sold out to the larger corporations or merged into a smaller number of more solvent concerns. One effect was that the major oil companies lost ground in the early 1950's in respect to gross acreage holdings. The fact that they have been at once more active and more discerning in so far as exploration and development are concerned, has had its rewards, however. At the present time, six of the largest internationally connected majors—Imperial Oil Limited, California Standard Company, Shell Oil Company of Canada Limited, The British American Oil Company, Limited, Texaco Exploration Limited and Mobil Oil of Canada Limited—hold, between them, about 40% of the gross acreage under reservation and lease in western Canada. They, at the same time, control about three-quarters of the proven oil reserves in this country.

INVESTMENT IN THE PETROLEUM INDUSTRY CANADA AND UNITED STATES 1946–1955





In recent years high bidding in provincial government land sales has prohibited the smaller companies with limited capital resources from acquiring land in the more favourable oil and gas areas. Reluctance to cancel expired though still remunerative leases has had a similar effect.

Oil pipelining in Canada has also become a major industry. Beginning with the construction of the Portland-Montreal pipeline in 1941 and given considerable impetus by the discoveries in western Canada after 1947, it has now grown to the point where main transmission lines with a combined length of 6,000 miles are in operation across the country. As a rule these facilities are operated by the large internationally connected oil companies. Ownership and control is overwhelmingly in non-resident hands.

Imperial Oil Limited is still the giant of the industry when it comes to the refining of crude oil. At the end of 1956 its nine refineries, located all the way from Halifax to Vancouver, accounted for 41% of the industry's total capacity. Next in line was The British American Oil Company Limited with 13%. Shell Oil Company of Canada Limited was third with 10.5% and McColl-Frontenac Oil Company fourth with 10%. Companies whose ownership still rests preponderantly in Canada accounted for less than 15% of total capacity. There is, however, an important role for the small refineries as evidenced by the fact that one-half of Canadian refineries have capacities less than 10,000 barrels a day.

In 1956, for the oil industry as a whole, control lay with Canadian companies to the extent of 21% while United States companies controlled 73% and other foreign companies 6%.

Table 13

TOTAL EXPENDITURES IN THE PETROLEUM INDUSTRY — CANADA AND UNITED STATES BY MAJOR CATEGORIES FOR THE YEARS 1946-55

Year	Exploration, development and production	Transportation	Refineries	Marketing	Total	Year	Exploration, development and production	Trans-portation	Refineries	Marketing
					Canada					
		(millions of dollars)						(percent distribution)		
1946	15	6	6	4	31	1946	48.3	19.4	19.4	12.9
1947	25	3	25	15	68	1947	36.8	4.4	36.8	22.0
1948	50	4	33	10	97	1948	51.6	4.1	34.0	10.3
1949	100	17	22	11	150	1949	66.7	11.3	14.7	7.3
1950	150	69	24	17	260	1950	57.7	26.6	9.2	6.5
1951	223	19	51	18	311	1951	71.7	6.1	16.4	5.8
1952	290	106	61	25	482	1952	60.2	22.0	12.6	5.2
1953	358	91	66	37	552	1953	64.8	16.5	12.0	6.7
1954	419	91	84	46	640	1954	65.5	14.2	13.1	7.2
1955	446	66	101	54	667	1955	66.9	9.9	15.1	8.1
Total	2,076	472	473	237	3,258	Total	63.7	14.5	14.5	7.3
					United States					
1946	1,385	165	250	200	2,000	1946	69.2	8.3	12.5	10.0
1947	1,830	295	400	300	2,825	1947	64.8	10.4	14.2	10.6
1948	2,215	310	600	225	3,350	1948	66.1	9.3	17.9	6.7
1949	2,090	250	420	240	3,000	1949	69.7	8.3	14.0	8.0
1950	2,160	215	275	275	2,925	1950	73.8	7.4	9.4	9.4
1951	2,715	285	325	300	3,625	1951	74.9	7.9	8.9	8.3
1952	3,265	385	470	280	4,400	1952	74.2	8.7	10.7	6.4
1953	3,600	425	675	325	5,025	1953	71.6	8.5	13.4	6.5
1954	3,875	325	800	350	5,350	1954	72.4	6.1	15.0	6.5
1955	4,165	225	835	375	5,600	1955	74.4	4.0	14.9	6.7
Total	27,300	2,880	5,050	2,870	38,100	Total	71.6	7.6	13.3	7.5

SOURCE: Canada — D.B.S. and provincial governments.
U.S. — *Investment Patterns in the World Petroleum Industry*, Chase Manhattan Bank, December, 1956.

A good deal of concern has been expressed, particularly in the United States, about the possibilities for survival of the small, comparatively non-integrated producer or refiner. The Canadian record, while it has its exceptions, also points up the advantage of size, international corporate ties and influence in other sectors of the industry's operations. Thus, the amount of crude oil refined by the small independents in the United States has fallen from around 24% of the total in 1935 to around 11% at the present time. (The figure for Canada in 1955 was approximately 12%.) Few small or independent concerns have managed to retain their identity in the pipeline business. They have managed to get much farther into the drilling and crude oil producing end of the business. In this they take a goodly measure of the risks but, in Canada, more often work under contract. If successful they still sell most, if not all, of their pro-rated output to the larger and financially stronger firms. Canada's case is only exceptional in that large companies are relatively more active in oil drilling than they are in the United States.

The following tabulation, which pertains to companies having a crude oil production or refinery run average of less than 10,000 bbls. per day, if it is indicative of a trend, shows that the opportunities for integration vertically towards the market are both limited and becoming less so with time.

Percent of Total Industry Activity Carried out by Small Companies

	United States			Canada
	1935	1946	1955	1955
No. of wells drilled	not available		78	56[a]
Gross crude production	41	37	38	30[a]
Refinery runs	24	15	11	12

[a]Included in the "under 10,000 barrels a day" category are numerous firms with international backing whose crude producing, transportation and refinery investments outside of Canada warrant their being ranked as sizable and often fully integrated producers.

Most successful oil undertakings do not start as integrated concerns, but the circumstances attending their various operations usually tend to drive them in that direction. On this continent, there have been wide fluctuations and different timing of profit opportunities within the various branches of the industry. This has made it attractive (or even desirable) to link up operations in more than one branch and so to achieve not only operational stability but also some stability of over-all earnings down the years. One of the most impelling forces in the past has been the comparative abundance or shortage of crude oil.

Investment, cost and profit considerations have been the most important factors influencing integration in the past. In both the refining and pipeline

phases of the oil industry, the plant and equipment employed is very expensive and highly specialized. It must, furthermore, be employed at full or near-to-full capacity, and if not utilized for its intended purpose is virtually worthless. Thus, integration by refiners, both forward into marketing and backward into crude production is a logical economic process. A parallel situation exists in the crude production sector, where very heavy and frequently unrewarding expenditures are normally incurred in the early stages of a new area's development.

A certain and stable outlet for the crude ultimately discovered is best assured by entry also into refining. As in other sectors of the oil industry, the high cost and specialized character of the equipment make full utilization important. In a setting of abundant supplies and keen competition it is natural to try to ensure this by linking, in one form or another, one operation with the next. The capital investment for the programmes of a progressive, integrated concern requires the accumulation of extensive capital resources. This, too, enhances the significance of stability in earnings, which is more likely to be obtained by a large and well rounded operation than by a small, non-integrated and comparatively unknown competitor.

Strengthening these obvious commercial tendencies toward integration are the many advantages which ensue from over-all planning. Co-ordinated investment in different sectors becomes possible, and highly useful and profitable investments may thus be made which, to a firm engaged at only one level in the industry, might appear to be of dubious financial worth. Thus, the logistical and storage problems posed by short-term but large-scale fluctuations in demand (for example the seasonal swings in the demand for heating oils) may be more smoothly met. Not only is the integrated concern able to link together its investment and operational decisions in respect to each sector of activity, but also it has available to it the fullest information on trends and prospects in every phase of the industry.

For these reasons the internationally owned and controlled firms will probably continue to dominate all phases of the oil industry in this country. Meanwhile, most Canadian independents, lacking these strengths, have little chance of becoming majors in the Canadian oil business during the next 20 to 30 years.

Financing of the Canadian Oil Development Programme

Under ordinary circumstances, no growing industry can finance all of its capital requirements from its own savings. Resort must occasionally be made to the capital market; that is, to outside sources of funds. The financial reserves of individuals and institutions are thereby mobilized in the expectation that they will be reimbursed out of future corporate income or, in the case of the sale of equity stock, through participation in the company's

profits. The media through which the oil industry usually obtains these outside funds includes borrowings from banks, insurance companies and other institutions and the sale of common and preferred stocks.

The relative importance of these various sources has changed over the past quarter century. In the 1930's, activity in the oil industry was regarded as much more hazardous financially than it is today. For this reason, the banks and insurance companies were less willing to lend their credit. Financing, to the extent that it could not be obtained out of company revenues, usually involved a sizable admixture of sales of preferred and common stocks. The opportunity for changes in corporate control, obviously, was much greater and the opportunities for individual participation in ownership much more widespread than today. In the interval, and particularly since the late 1940's, the oil industry has become much more respectable. Today, it has much less difficulty in borrowing money. Issues of preferred and common stock are held to a minimum and the industry's existing corporate structure, therefore, tends to be much more perpetuated.

These trends in financing are clearly illustrated in reports which have been issued from time to time by the Chase National Bank. They show that the industry is generating a much larger proportion of its investment capital internally from revenue, and hence relying much less on external sources, than was the case 20 or 30 years ago. Again, and in respect to external sources of financing, other changes have been taking place. Whereas the public supplied 90% of the funds obtained outside the industry in the mid-1930's, banks and insurance companies together now provide almost 60% of such funds. With this relative decline in preferred and common stock offerings the opportunities for decided change in ownership and control are reduced and this applies with even greater force in Canada than in the United States.

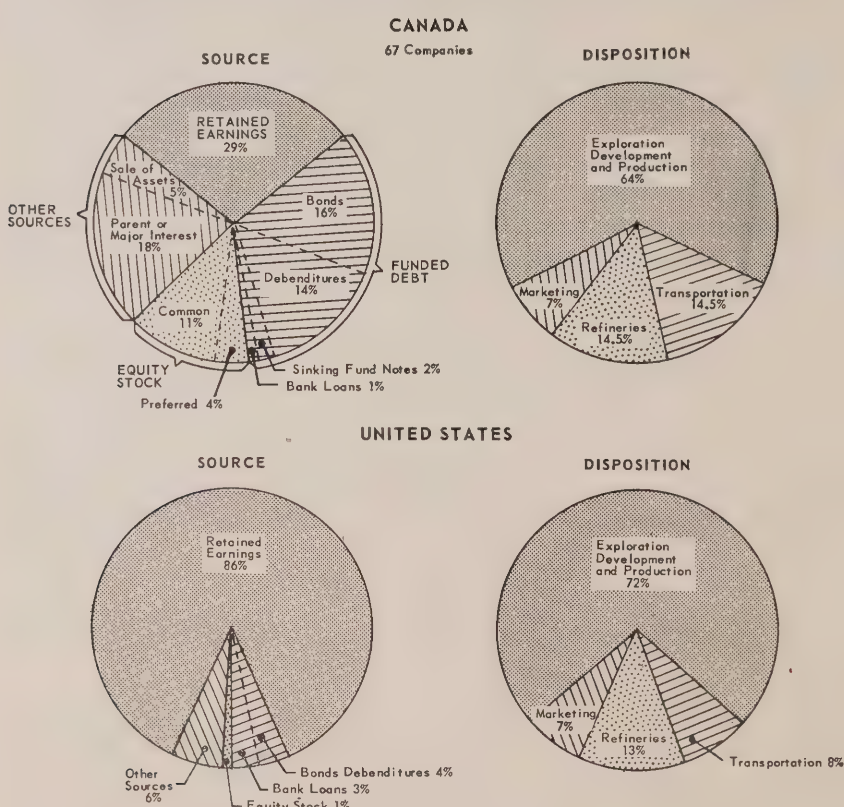
As far as Canadian participation is concerned, another factor also has to be taken into account. With three-quarters or more of the oil industry integrated abroad, only a relatively small proportion of the equity issues are ever offered for sale in this country. Again, when issuances are made, substantial blocks are reserved for purchases by the major oil companies themselves. Of the remainder, half or more is often released in the principal money markets of the United States. The net effect of all this has been that most of the Canadian money finding its way into the domestic oil business has gone towards the purchase of bonds with a limited life and a guaranteed rate of interest rather than into the riskier and frequently more lucrative field of outright ownership.

Unless the policy of a number of the major companies changes in this respect, there may be even less opportunity for Canadian nationals to buy into the oil industry in future. The most difficult phase, in so far as the raising of investment capital is concerned, is largely over. Revenues from the sale of crude oil production are now on the increase. Within the next

few years they may be sufficient to cover the industry's total expenditures on exploration, development and production. No longer will parent companies be required to pour millions of dollars into Canada with little chance of earning a return for a decade or more. Also, there is less likelihood of companies like Imperial Oil selling, outright, their interests in subsidiary companies in order to obtain sufficient funds to carry on an accelerated programme of exploration and development. From now on, therefore, it looks as if the plowing back of retained profits from crude sales and Canadian refinery operations will play much more rather than a less important role in the providing of future capital for growth in this country.

The accompanying chart, Source and Disposition of Funds Employed in the Petroleum Industries of Canada and the United States for the Years 1946 to 1955, contrasts the importance of retained earnings in the two countries.

SOURCE AND DISPOSITION OF FUNDS EMPLOYED IN THE PETROLEUM INDUSTRY – CANADA AND THE UNITED STATES 1946–1955



Source and Disposition of Funds Employed in the Petroleum Industries of Canada and the United States 1946-55

	Canada		United States	
	Millions of dollars	Percentage of total	Millions of dollars	Percentage of total
Source[a]				
Provided by Earnings	819	29.1	26,787	86.1
Funded Debt	936	33.3	2,035	6.6
Bonds	437	15.6		
Debentures	406	14.4	1,221	4.0
Sinking Fund Notes	51	1.8		
Bank Loans	39	1.4	814	2.6
Promissory Notes	3	0.1		
Equity Stock	425	15.1	401	1.3
Preferred	107	3.8		
Common	318	11.3		
Other Sources	631	22.5	1,874	6.0
Parent or Major Interests	506	18.0	168	0.5
Sale of Assets	125	4.5	1,706	5.5
Total all Sources	2,811	100.0	31,097	100.0
Disposition				
Exploration, Development and Production	2,076	63.7	27,300[b]	71.6
Transportation	472	14.5	2,880	7.6
Refineries	473	14.5	5,050	13.3
Marketing	237	7.3	2,870	7.5
Total Disposition	3,258	100.0	38,100	100.0

[a]In this analysis the measured source of funds is 86.3% of total disposition of funds for Canada and 81.6% for United States.

[b]Includes cost of drilling dry holes and lease acquisitions but excludes exploration expenses and lease rentals; these latter charges are, however, excluded in the Canadian total of $2,076 million.

8

NATURAL GAS

Section I: Introduction

The use of natural gas both as a fuel and as a raw material is increasing rapidly. In the early 1920's consumption was still confined to areas close to the gas fields. Wastage, as a result of operations in the oil industry, was considerable.. Since then, however, a number of things have happened. First, satisfactory methods were developed for the fabrication in quantity of large diameter, high-pressure steel pipe. Then, as special pipe laying machinery became available, the building of long distance transmission lines began. Improved conservation practice made available large quantities of natural gas to the newly formed transportation utilities. Prices, particularly at the field, were favourable and soon its properties as the cleanest, most convenient and most readily controllable of fuels began to be recognized in centres which had never before been served in this way. As a result of all these developments natural gas began to be transported first hundreds of miles, and later distances up to 2,000 miles, away from its point of origin.

Over the past thirty years expansion in this industry has been nothing short of spectacular. Consumption in North America has risen sixfold since 1935 and considerably more than doubled since 1945. Its use as a source of energy has therefore been rising in relative as well as absolute terms. Gaining on coal ever since 1900, it is now overhauling oil in a number of its major markets as well. From less than 5% a quarter of a century ago it now supplies about one-quarter of the total energy needs of the United States. (By contrast, natural gas' share of the Canadian energy market, though rising rapidly, is still only 6%.)

Natural gas is, today, the cheapest source of energy for many purposes. Long-term supply contracts have helped to hold its price down to former levels. Because of efficiencies of scale, load balancing and the increasing use of terminal storage, capital charges per unit of throughput have tended

to decline rather than increase. Salaries and wages are a relatively small item of expense. Natural gas, the production, transmission and distribution of which requires fewer man-hours than the other fuels, is therefore less vulnerable during periods of inflation. Since the general price level may continue to edge upward over the next quarter century, this novel fuel, because of the dominance of capital charges in its cost structure may continue to enjoy an advantage over oil and particularly coal in many areas and applications.

Favourable prices are not the only reason for its being in such demand. Gas stoves, furnaces and other equipment are usually cheaper to build, to install and to maintain. The question of user inventories, as with electricity, does not arise. In industry, natural gas is usually preferred in situations where extreme cleanliness and accurate temperature control are essential. Experience has also shown that supplies are rarely jeopardized by labour disputes and that the fire hazard and poisonous effects of the older manufactured product can be largely eliminated. With all this in its favour there will probably continue to be more customers waiting to be served than there are proven gas reserves, pipelines and distributing systems available to supply them.

In reviewing the principal trends underlying the growth and demand for natural gas one must concern himself with three main groups of customers; that is to say, household, commercial and industrial users. The first two, while they account for less than one-third of the total volume of natural gas marketing on this continent, pay much higher prices. Consequently they provide two-thirds or more of the industry's total revenue. Industrial users, meanwhile, pay much less. They absorb about 70% by volume of all the gas produced on this continent.

On the average, household consumers pay about three and a half times and commercial users about two and a half times as much as industrial concerns. The latter are charged less not only because of their high volume use per individual connection but also because they are prepared to take gas at times when it cannot be sold more advantageously to customers in the higher-priced brackets. Thus industry, as a result of its willingness to buy on an interruptible basis, helps to keep the main transmission lines and distributing systems operating at or near maximum capacity 24 hours a day and 365 days a year.

While the residential and commercial markets for natural gas constitute the financial backbone of most natural gas operations, a substantial volume of industrial sales is also essential to the financing of most longer lines. The highly variable nature of space heating and certain other household and commercial loads would, if served exclusively, result in relatively low pipeline and distributing system load factors. Terminal storage when used to absorb the over-run helps. However, it is the more highly diversified indust-

rial communities which can usually be served most economically by long distance pipeline gas.

Industrial uses vary both as to price and location. Oil and gas field operations are still the most important in volume terms. Not only is a great deal of natural gas employed in lifting oil to the surface but it is also essential to secondary crude recovery and pressure maintenance programmes. Further quantities are burned in drilling and pumping equipment. In all, about 15% of North America's total gas production is being used in or near the oil and gas fields themselves. The growth of alternative markets, greater knowledge of underground reservoirs and their behaviour and improved conservation practices are all helping to reduce this figure.

The next largest industrial use is the production of electricity. Currently, this application absorbs one out of every ten cubic feet produced.[1] Here again, consumption is confined largely to the main producing areas. Carried 500 miles or more, natural gas becomes too expensive to be used in the continuous firing of power plant boilers and gas turbines. Under these circumstances, it can rarely be laid down at prices competitive with the cheaper grades of steam coal. There are exceptions of course. A few utilities remote from the producing fields and lacking low-cost water power or coal resources of their own have found it best to use natural gas in thermal plants seasonally or otherwise on an interruptible basis.

Both the oil refining and petrochemical industries have been wont to turn to natural gas. Refineries converting crude oil into petroleum products now use about 7% of all the natural gas marketed commercially on this continent. Priced low enough it can be burned in lieu of a number of the lighter petroleum fractions which are then sold more profitably for the production of organic chemicals or of bottled gas. The amount of natural gas which is converted directly into other petrochemicals presently amounts to about 2% of all North American consumption by volume.

Cement production is another substantial consumer of natural gas. Numerous plants within several hundred miles of the gas fields have, for reasons either of price or of labour and other economies converted entirely to the use of this fuel. Intermittant purchases are also made by cement manufacturers who can be served by the longer main transmission lines. During periods of peak gas demand these installations, like other heavy industry, frequently shift over to coal or oil or shut down, as they eventually must, for overhauls.

Many other manufacturing industries are employing natural gas. Some are large volume users paying low to medium prices. Others use natural gas more sparingly and pay premium prices which reflect its intrinsic value

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[1]This ratio applies essentially to the United States. Comparatively little natural gas is, as yet, used for the generation of electricity in Canada.

in their operations. The primary steel mills are beginning to use natural gas more in their open hearths instead of residual oil. Other metallurgical plants are employing it both as a source of process chemicals and for the generation of heat. Brick plants and glass producers prefer natural gas over other fuels on grounds mostly of quality. In the production of foods its cleanliness aids in processing. Secondary industries engaged in the fabrication of metals and the production of secondary chemicals also prefer natural gas when it can be obtained at a price comparable to that charged for oil. Unlike the major consuming industries discussed previously, they are generally to be found in and around the main industrial centres—that is, at a distance from the principal areas in which gas is produced.

Market forces, though they are delayed in their effect, are tending to divert an increasing volume of gas into the higher-priced applications. The number of residential, commercial and small industrial customers is rising rapidly. Meanwhile, fewer contracts are being written which will permit bulk sales to heavy industry at low prices, or in circumstances in which these demands could reasonably well be served using coal or a residual oil.

Rising costs are also a factor. On the average, natural gas is having to be transported over much greater distances. Hence an increasing proportion of the industry's expenditures is taking the form of capital outlays on main line transmission and distributing facilities. Market factors are having a similar effect. Gas at the field is being bid up to a price more in line with oil at the wellhead and coal at the mine. With these forces at work, additional reserves of natural gas are being sought for and even larger volumes committed to distant and highly diversified markets in a manner quite different from that characterized by other branches of the petroleum industry.

Section II: Background of the Industry

Regional Developments in United States

Natural gas is now—or soon will be—offered for sale in all of the principal fuel consuming areas of North America. Projects approved and presently under construction will see the inclusion of the United States Pacific Northwest, British Columbia, Manitoba and most of Ontario and southern Quebec. After that the Atlantic provinces will be the only major region on this continent remaining to be served. Possibly by 1980, with further improvements in long distance pipeline transmission and the development of pressurized tanker and other water transport, even they may have access to this unique source of fuel and chemical raw materials.

Only in the postwar period has natural gas begun to move in volume into the more highly populated Eastern and North Eastern States. Ten years ago the larger cities, from Washington to Boston, were regarded as strongholds of manufactured gas. Today the situation is quite different.

Now practically every gas utility along the Atlantic coast is engaged in marketing natural gas alone or as a mixture with the artificial product.

The demand for natural gas is just as pressing in parts of the United States which have used it for years. The Appalachian region, which includes most of Western New York and Pennsylvania, Kentucky, West Virginia and Ohio, is a case in point. Many natural gas distributing utilities can trace their beginnings back to the 1870's and 1880's when sizable gas reserves were discovered in those states. Later as production began to diminish, it became necessary to supplement local production with gas from the newer and much more extensive fields in the southwest. Now practically all of the growth requirements of the region are being piped in from Texas and Louisiana.

Some of the lines running into the middle west were built when construction costs were less than half of what they are today and gas in the ground could be bought for a fraction of its present wellhead value. Many of the supply contracts on which they were financed are still in effect. Low prices, meanwhile, have stimulated demand. So much so that restrictions on the installation of new gas burning equipment have, at times, had to be imposed on industry in order to ensure adequate supplies for existing customers. In an attempt to meet these deficiencies half a dozen new pipelines have been built from the Gulf coast area to serve Detroit, Chicago and other middle western centres since 1945.

Another large utility market for long distance pipeline gas is California. Still relying largely on its own resources as late as 1950 this state now consumes half as much as the entire middle west and is now facing a gas shortage. Since World War II no major discoveries have been made and it has therefore been necessary to turn to more remote sources such as west Texas for additional supplies. Rising prices and the dedication of reserves in these other producing states to local, middle western and eastern markets have resulted in a growing interest in western Canadian gas. particularly that which could be moved directly southward through Washington and Oregon into northern California.

While some of the northern states such as Montana and Wyoming have been supplied by local fields, the United States Pacific Northwest has only now begun to switch over from the manufactured gas. Geographical considerations indicate that western Canada is its logical source of supply. However, for a few years, gas from New Mexico will also be entering Washington and Oregon in substantial volume. Deliveries commenced late in 1956.

The following table which records the growth in consumption of the principal gas consuming areas of the United States also gives an idea of their present order of magnitude:

Quantity in Billions of Cubic Feet

Region	1932	1935	1940	1945	1950	1955
New England	—	—	—	—	—	65
Middle Atlantic	70	127	148	179	332	708
East north central	56	183	280	394	761	1,274
West north central	41	156	222	334	592	898
South Atlantic	101	66	111	143	246	451
East south central	38	45	77	133	298	525
West south central	924	963	1,330	2,015	2,722	3,541
Mountain	62	86	135	200	391	586
Pacific	263	284	352	502	684	1,021
Total U.S.	1,555	1,910	2,655	3,900	6,026	9,069

SOURCE: All years—U.S. Bureau of Mines.

Regional Developments in Canada

To date, natural gas has accounted for only a small part of Canada's total fuel requirements (*i.e.* 6% in 1955). Its use in that year was still confined to central and southern Alberta, central Saskatchewan, western Ontario and the immediate vicinity of Moncton, N.B.

Over the next few years all this will change. Utilities in most of the larger cities and towns in British Columbia, southern Saskatchewan, Manitoba, Ontario and southern Quebec will be supplied by the Westcoast and Trans-Canada pipeline systems by 1960. Later, extensions designed to serve new export markets or to supply certain isolated manufacturing plants in Canada will bring in an even greater proportion of the population within the orbit of this industry's activities. However, before attempting to assess the size and probable rate of growth of these outlets let us review briefly the record of past developments in this country.

Southern Ontario

Much of the natural gas used in Ontario is still being drawn from the fields in the southwestern corner of the province. This well known source area, which is generally more widespread than that yielding oil, borders on Lake Erie. There geological structures in which gas is being found resemble similar gas-bearing formations paralleling the Appalachian Mountains in the United States. Available drilling records and other geological data indicate a definite northern limit to these occurrences.[2] Southward, however, pockets of gas are known to exist along the shoreline and out under Lake Erie.

[2]The Canadian Shield, the southern limit of which runs from Georgian Bay to the St. Lawrence River near Kingston, contains no structures suitable for the occurrence of either oil or natural gas.

Gas from this general vicinity, which was marketed as early as 1880 and at one time exported to the United States, is still being distributed in centres such as Sarnia, Windsor, Chatham, London and Niagara Falls. Output, while it has held up well in recent years, is not believed to be capable of considerable expansion. Over the past decade it has been supplemented both by gas manufactured from coal and oil and by imports from the United States.

Supplies bought from nearby American systems have only become significant since the end of World War II. At first brought across the Detroit River at Windsor as summer surplus gas and stored underground in exhausted oil and gas fields, it has since been supplemented by year-round supplies entering Canada at Niagara Falls and destined primarily for use in the Toronto area. While these quantities, including local production, are far from being adequate to meet the future needs of Canada's most highly industrialized province, they have been useful in building up sales preparatory to the arrival of much larger quantities of gas from western Canada.

Alberta

As is the case with oil, Alberta possesses reserves many times those discovered elsewhere in this country. Even though sizable finds have also been made in British Columbia and, to a lesser extent, in Saskatchewan, close to 90% of all the natural gas used in Canada is produced there. Also, in contrast to Ontario where proven reserves are barely adequate to support existing contracts, output has been rising rapidly and a mounting surplus has been declared available for export.

The natural gas industry—as of 1955—was still largely confined to the southern half of the province. The known fields which are more scattered than those producing oil are found in the foothills region of the Rockies and out on the Great Plains, all the way from the International Boundary to the Peace River District. Available drilling records and other geological data have not as yet indicated any clear cut eastern or northern limit to future discovery possibilities.[3]

At the present time the Turner Valley supplies about one-fifth of all the gas consumed in Alberta. Along with a newer pool at Jumping Pound, it serves Calgary, Lethbridge, and a number of other communities in the southern part of the province. Edmonton is supplied principally by the Viking Kinsella field, still the second largest gas producing area in the province.[4] Towns as far south as Red Deer also draw gas from this source. Meanwhile, an extensive grid or network of export and local distributing lines is gradually being built up to serve most of the other and smaller cities and towns in Alberta.

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[3]The Canadian shield is found only in the extreme northeast corner of the province.

[4]Augmented by gas recovered from the oil operations at nearby Leduc.

The discovery of gas in Alberta dates back to 1884 and commercial production to about 1904. In the latter year, supplies of gas were first drawn from shallow wells at Medicine Hat. In 1909, the Bow Island field was discovered and three years later a 170-mile, 16-inch line was built to pipe natural gas to Calgary.[5] Gas had been detected in the Turner Valley at a very early date but the discovery well was not drilled until 1913. Extensive development in Turner Valley did not begin until 1936 when oil was discovered there. Dry gas was found in the Kinsella area in 1914 and transmission to Edmonton commenced in 1923.

After 1924, the situation in Alberta was dominated by Turner Valley, first as a gas-condensate and later as a crude oil field. During the late 1930's, drilling operations declined. Production was then greatly in excess of market requirements. At least one trillion cubic feet are estimated to have been wasted by flaring at the wellhead. It was not till after the discovery of oil that voluntary conservation practices and measures enforced by the Alberta Petroleum and Natural Gas Conservation Board helped to reduce wasteful withdrawals from this and other fields.

The discovery of crude oil in 1936 gave considerable impetus to exploration activity and other wells were drilled along the foothills of the Rockies and out on the southern plains. However, production of crude oil in Turner Valley began to decline during World War II, and the search for petroleum turned elsewhere, with the discovery of natural gas as an important (though secondary) objective.

With crude oil having to be imported, the possibility of synthesizing gasoline from natural gas came under active consideration. Plans for production on a large scale were well advanced by the end of World War II. The Leduc crude oil discovery in 1947 caused them to be discarded. Not only was the idea of manufacturing liquid fuels abandoned, but the possibility of exporting gas was much enhanced. Southern Alberta's proven gas supplies began to rise in response to an oil drilling programme which, by 1955, had embraced some three-quarters of the Province's total land area. Large individual discoveries such as those at Jumping Pound and Pincher Creek were supplemented by numerous others scattered across the Province from the International Boundary in the vicinity of Medicine Hat northward and westward to the Peace River District in British Columbia. While many of these reserves are still shut in for lack of immediate markets, supplies recovered by gas conservation plants in the oil fields have been given priority and since sold for local consumption within the Province.

Other parts of Canada

Production in western Canada is by no means confined to Alberta. Fields in the Lloydminster area of Saskatchewan have, for well over a

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[5]At that time, there was only one other line of similar length in the world; a 185-mile, 16-inch line in Louisiana.

decade, been supplying nearby towns in that province. More recently, with major discoveries being outlined in the Unity, Brock and Coleville areas, gas in volume sufficient to supply the cities of Saskatoon and Prince Albert has been dedicated for this purpose, and provincially owned transmission lines and local distribution grids are now in operation there. Plans are well advanced for the inclusion of Regina and other centres which are better located to take advantage of the accelerated oil and gas exploration and development programmes presently being carried out in the west, central and southern parts of Saskatchewan.

Production in British Columbia is only in its infancy. However, with the completion to Vancouver of the large diameter Westcoast project late in 1957, output will rise rapidly. So much so that, by 1960, British Columbia will head all other provinces with the exception of Alberta.

The following statistics indicate the relative importance and rates of growth of natural gas sales in Canada's three main gas consuming provinces:

Quantity[a] in Billions of Cubic Feet

Province	1930	1935	1940	1945	1950	1955
Alberta	20.7	16.1	27.5	40.4	51.5	121.7
Saskatchewan	—	0.1	0.1	0.2	0.8	6.7
Ontario	8.0	8.2	13.1	7.2	14.1	22.6

[a]Sales of locally produced gas imports in the case of Ontario.

Proven and Probable Reserves

As one traces the ever mounting growth in gas sales on this continent he begins to wonder whether there will be adequate supplies to look after these burgeoning demands, decade after decade. No sooner are new transmission lines built than they are having to be looped (or paralleled) by entirely new ones. Customer saturation, though proceeding apace, has not yet been achieved even in the more favourably situated areas where natural gas has been available for 20 or 30 years. Elsewhere—and this applies to some of the more densely populated parts of the United States and Canada such as New York State and Southern Ontario—gas is only now being offered in quantities even approaching those of the other fuels. For this reason regulatory bodies at the state, provincial and federal levels are being continually reminded of the need to look after the long-term requirements of their own people first and to make only such supplies available for export as clearly exceed the source area, region, or the country's own 20- to 30-year requirements.

There have always been "experts" in the industry who are inclined to take a gloomy view, claiming that it was unrealistic to assume that discoveries could keep pace with demands which were likely to double every five

to ten years. So far they have been wrong, but their ranks have been growing. Statistical evidence, while by no means conclusive, points towards a diminishing margin between proven supplies and effective demand in the 1960's and 1970's.

Because of their longer history, United States statistics make interesting reading. There the ratio between proven reserves and production (years of supply) has averaged out at around 25 years. Varying from year to year, it rose to 40 years in 1946 and tumbled to 23 years in 1956. The industry has witnessed this kind of thing before. The United States had 13 years' requirements in sight in 1924 and only 12 years' supply on hand as late as 1929. Supply, in other words, responds though belatedly to demand. The successes which have been achieved in recent years offshore along the Gulf coast and in Texas, Louisiana and New Mexico give further assurance that the demands of a number of new pipeline systems can be met before deficiencies on the supply side necessitate the synthesis of a similar high B.t.u. content gas from other and more abundant fuels. (See chart: Net Production and New Additions to Gas Reserves U.S.)

The following table summarizing this information lends further credence to the view that United States sources may be able to look after most if not all of the demands which are likely to emerge in that country over the next quarter century.

Quantity in Billions of Cubic Feet

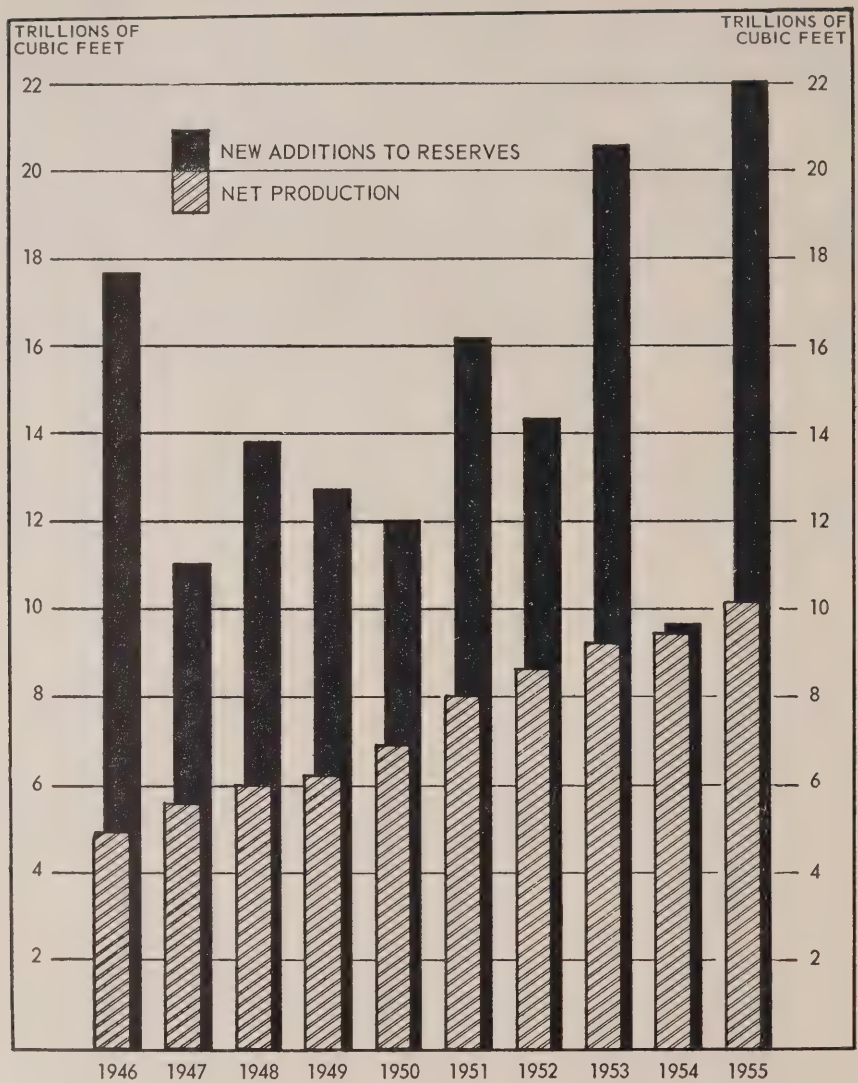
Year	1920	1930	1940	1950	1955
Production	798	1,943	2,660	6,200	9,380
Proved reserves (Dec. 31)	15,000	46,000	85,000	186,000	224,000
Years of supply	19	24	32	30	24

SOURCE: *Twentieth Century Petroleum Statistics,* Degolyer and MacNaughton (as compiled from American Gas Association reports and other authoritative sources).

In Canada, by contrast, search for natural gas has barely begun. Even today fewer than two dozen firms, large and small, are devoting their efforts full time to the proving up of additional gas reserves. Furthermore, the efforts of the majority of those which are already in business have been confined to the last five or six years; only since 1950 has there been any prospect of their marketing a substantial proportion of their output in centres outside of Alberta.

The reserve possibilities of the Western Prairie Region appear to be considerable. Witness the fact that proven resources in Alberta have moved upward from an acknowledged 4.7 trillion cubic feet in 1950 to around 16 trillion cubic feet at the end of 1955. Since the early 1950's three trillion

NET PRODUCTION AND NEW ADDITIONS TO GAS RESERVES IN THE UNITED STATES



cubic feet have been proven up in the nearby Peace River District of British Columbia. Another trillion is now available in Saskatchewan. In total, Canadian reserves at the end of 1955 were in the vicinity of 21 trillion cubic feet.[6] At the then current rate of consumption, this was equivalent to more than 100 years of supply.

Section III: Prospective Markets for Canadian Gas

After reviewing the growth of the natural gas industry on this Continent, both in terms of its industrial applications and in terms of its established markets, one is tempted to let one's imagination take over, and to visualize within a relatively short span of time a continent wide network of long distance and feeder pipelines reaching out to serve most of the cities and towns in the United States and Canada.

The part which Canadian sources will play will depend, of course, on the success attending the search for liquid fuels in this country. But markets—or more correctly, access to markets—may also be a major determinant of development in the years ahead. At least 50 million people already live within economic pipeline distance of the Canadian fields. Many of them—and this applies particularly to those in eastern Canada—pay prices for fuel well above the North American average. Other possible sources will be fully occupied. It is therefore likely that, by 1980, half a dozen major gas transmission lines originating in the western Canadian plains or foothills country will be reaching down across British Columbia into the western United States or threading their way eastward to serve the homes and industries of eastern Canada and the United States middle west.

Having examined the economics of marketing crude oil in the previous chapter, we are tempted to draw a parallel with natural gas. Frequently, the source areas are the same. The distances and country over which both commodities have to move to market are comparable, if not identical. The markets themselves, while corporately and institutionally much more monopolistic in the case of gas, involve common considerations as to price and quality. Indeed, were it not for the very different arrangements under which natural gas is procured and sold, the marketing of these two fuels might be considered as analogous one with the other.

Natural gas is a less transportable commodity than crude oil. Were its wellhead price the same, it could not move as far, either east or west, and still manage to compete effectively with other fuels. But this is not so.

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[6]The Canadian Petroleum Association has estimated that, at the end of 1955 Canadian proven and probable gas reserves were in the vicinity of 20.8 trillion cubic feet. Proven recoverable reserves were put at 16.5 trillion cubic feet. Non-associated gas, *i.e.* independent of oil production, was estimated to be 12 trillion cubic feet; that associated with oil at 2.6 trillion cubic feet and dissolved in oil 1.9 trillion cubic feet. Hence some three-quarters of Canada's presently proven recoverable gas reserves can be regarded as independent of crude oil production.

Except in certain regions, natural gas is still, essentially, a by-product of the search for oil. A large part of its associated exploration and development expenditures are, therefore, written off against crude petroleum. In circumstances where it is produced jointly with oil it is, to all intents and purposes, free at the wellhead. The sale of such desirable constituents of wet and sour gas as propane and sulphur also helps. Consequently the price of the clean, dry product at the field is much lower than it would otherwise be.[7] This, indeed, is the main reason why natural gas has been able to move a thousand miles and more to market and still win customers away from oil in a number of its higher priced and larger volume applications.

Because of its similar remoteness from markets, Canadian gas is under much the same penalty as western Canadian oil. Its netback over a greater number of transmission line miles is lower than that accruing to producers in better situated areas in the United States. This is certainly true of prospective movements into the Chicago and Montreal areas. Only in selling locally in western provinces, in midwestern states like Minnesota and down the west coast do the Canadian fields enjoy a potential advantage in this respect. Hence, it is frequently argued that Canadian and export outlets within a 1,500-mile radius of the Alberta and British Columbia fields are likely to be the most remunerative to the producing end of the business.

One is tempted to go even further; to argue for a government sponsored exchange of gas. In these circumstances, Canadian resources would be used to supply consumers in western Canada and adjoining areas in the United States. Imports in comparable volume might be brought in from the United States to service Ontario and southern Quebec. By constituting a better international division of labour such an arrangement would, theoretically at least, be in the best interests of both producers and consumers.

Unfortunately production in the United States is already tending to outrun the discovery of additional reserves. Most American experts envisage a time when new pipelines will have difficulty obtaining 20 or 25 years of supply. Already they are confidently forecasting a steady rise in price and a more zealous rationing of industrial and export demands.

These conditions, together with the problem of obtaining imports from the United States as and when eastern Canadian consumers want them, have already served to limit the amount of American gas entering southern Ontario. Nor are these difficulties likely to diminish. With the largest and

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[7]A wellhead price for dry, clean, natural gas of 10c per thousand cubic feet (the average for Alberta at the present time) is equivalent to a wellhead crude oil price of around 60¢ per barrel. Western Canadian oil is selling in the field for approximately $2.50 at the present time. Ten-cent natural gas is also equivalent to a bituminous coal price of around $3.00 per ton.

most demanding of the United States markets lying astride all of the conceivable routes over which consumers in central Canada could be serviced from the mid-continent and Gulf coast fields no one in Ontario and Quebec—least of all heavy industry—could confidently plan for a steady annual increase in sales based on United States gas. Indeed, the opportunity of exporting in the opposite direction from an all-Canadian line appears to be increasing. Therefore, apart from an initial buildup period terminating in 1959 or 1960 imports into the eastern half of the country may be limited to such amounts as can conveniently be exchanged to meet peak demands on either side of the International Boundary.

Meanwhile sizable outlets for Canadian gas are only slowly being established. Natural gas service, being of the nature of a public utility, is almost everywhere under government regulation. Export sales are contingent upon the approval not only of provincial authorities but also of the Canadian government and United States Federal Power Commission. Long-term contracts, 20 or more years in duration, have to be secured both from proven suppliers and established distributors. Local franchises are also involved. Thus political considerations can, and often do, arise at various levels. Delays and disappointments are inevitable.

Most promotions—especially those of any size—are consequently up against a series of discussions, negotiations, hearings, interventions, and reassessments of their position which may well take years to resolve. These delays add substantially to the cost of each project. When with all its modifications it is finally approved, the terms and conditions to which the new line must conform are often such as to reduce its profitability below earlier expectations.

Propositions involving the export of gas to the United States are also susceptible to settlements or compromise solutions—terms imposed through the medium of the United States Federal Power Commission—which are designed, primarily, to look after the best interests of Americans as consumers.

Recent rulings in respect to the Westcoast Transmission project are a case in point. The Canadian line, as originally conceived, was to have serviced the entire needs of the Pacific Northwest (*i.e.* British Columbia, Washington and Oregon). Its economics were based on (a) obtaining a market price competitive with other fuels on the west coast and (b) the comparitive nearness of the Canadian gas fields in the Peace River District. By refusing its application and favouring a longer all-American line, the United States Federal Power Commission allowed no alternative to the Canadian producers but to sell their gas as if it were competing in the next closest market, *i.e.* northern California. In attempting to compete over this much greater distance the price at the International Boundary had to be cut back. Also, in reaching a settlement with their erstwhile opposition,

the Pacific Northwest Pipeline Company (who then became part owners of the Westcoast project), another condition was attached. It was to the effect that the border price was to remain fixed over the full 20-year period of the contract; a stipulation unique in North American gas history.[8]

Regardless of the manner in which a settlement was reached it now appears that this Canadian gas will, in effect, supply the needs of the Pacific Northwest. It will be performing the same task as the proponents of the original Westcoast scheme intended it to perform. But it will be doing so at a price well below that which could have been secured had the Canadian fields been recognized from the outset as the logical (and only adequate) source of supply for this rapidly growing market. Meanwhile, gas from the Four Corners region of New Mexico which temporarily is performing this function will soon be released for sale at more remunerative prices locally in the Rocky Mountain states, in Colorado and in California.

The net-back to Canadian fields is being squeezed and squeezed in similar fashion in respect to exports to the United States middle west. In anticipation of a similar ruling from the United States Federal Power Commission, Canadian gas (from the Trans-Canada Line at the border south of Winnipeg) has been contracted at a price which takes into account the need to build a supplementary line northward in the Minnesota area from the United States gas fields in Texas. Again, as a result of price setting at the point of entry, some part of the capital charges on this alternative American supply line must be assumed by producers in this country.

The situation with regard to exports into the State of Montana illustrates, perhaps in exaggerated fashion, the lack of awareness in this country both of the broader Canadian interest in these matters and the intricacies of parent-subsidiary trade spanning the International Boundary. Though natural gas has long been in use, resources on the American side do not appear to be adequate to meet all the growth requirements of Montana, Idaho and the western Dakotas. It is logical, therefore, that dry gas which is available a few miles away in southwestern Alberta should find an outlet there. Its price, however, should be directly related to that charged for competing fuels. Were this to be the case the net-back in Canada would be in line with some of the highest field prices charged anywhere in North America.

This, however, is not the case. The Canadian subsidiary of the Montana Power Company has been permitted to charge its parent a price at the International Boundary comparable to that prevailing in other fields in Alberta. Canadian gas, priced in this way, is being delivered at the

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[8]In arguing in support of the Westcoast application, the brief of the Pacific Northwest Pipeline Corporation states that "One of the outstanding features of Pacific Gas' purchase contract with Westcoast is that the purchase price of gas (22¢/M.c.f.) is firm for the full twenty year period of the contract. The contract is devoid of escalation provisions. We know of no other situation comparable with this."

Anaconda Smelter in Butte, Montana, at a cost to that company between one-half and one-third of that which it would otherwise have had to pay for energy in the form of coal or residual oil. Had the forces of supply and demand been allowed free play, the return at the producing level would therefore have been higher and the profitability of the Canadian operations of the Montana Power Company would have approximated much more closely that of natural gas operations in similarly situated fields in the United States.

Finally, mention should be made of the prospective movement of Alberta gas eastward across the country through Ontario to Quebec. In view of the opposition which was likely to be forthcoming from certain interests in the United States and because of past difficulties in obtaining the support of the United States Federal Power Commission, the possibility of following an international route was eventually discounted. Canadian government policy, which was also aimed at establishing a prior claim on Canadian gas for Canadian consumers, therefore supported an all-Canadian route. Not only has this meant building a much larger diameter line over more difficult and sparsely settled terrain, but the necessity of paying Canadian sales tax and duties has also added to the cost of its construction. Transportation charges, in other words, are higher than they would have been had it been possible to build this line along an easier route such as that followed by the interprovincial oil pipeline south of the Great Lakes to Sarnia. Again, with the market price of gas in central Canada fixed by competition with the other fuels, this has had the effect of setting a lower ceiling on prices in the field. Yet, because the Trans-Canada line promises to provide an earlier outlet for proven gas than would otherwise have been available it has much to recommend it from the producers' point of view.

Concerned with the need to comply with broader policy considerations and, at the same time, with the need to build up large volume markets in areas where natural gas as a fuel has been comparatively unknown, progress to date has been slow. One can also understand, from what has been said, why the latest Canadian field prices are still well below those prevailing in the major source areas in the United States. How much lower is illustrated by the following table.

Viewed in its longer time perspective the 15-year period from 1945 to 1960 may be seen to have been a difficult but necessary prelude to much greater things. Demand throughout North America will continue to be both strong and persistent. Markets once tapped will grow rapidly. Geographically, the Canadian fields are well situated to supply the growth requirements in a number of adjoining areas in the United States. Arms length bargaining between competing corporations will eventually yield a much better return at the field. Also, as the United States authorities gain confidence in Canada as a source of supply, the price at the boundary is less likely to impose a ceiling upon field net-backs in this country. In other

Recent Field Contract Prices in Cents/M.c.f.[a]

Canadian Source Gas			United States Source Gas		
Destination	Route	Field price	Destination	Route	Field price
Pacific Northwest	Alta. - B.C.[b]	6	Pacific Northwest	New Mexico[e] - Washington	14
Montana	Alta. - Montana	10	Montana	Wyoming - Montana	14
U.S. middle west	Winnipeg - Minneapolis[c]	10	U.S. middle west	Oklahoma - Minnesota[f]	22
Eastern Canada	All - Canadian[d]	10	Eastern Canada	U.S. Gulf Coast - Toronto[g]	19

[a]These are starting prices and apply only to new contracts. Most supply contracts include escalation clauses operative over their 20-year to 30-year life. Rising at one-quarter cent a year, a 10¢ initial delivery contract would yield 15¢/M.c.f. at the end of 20 years.

[b]As presently followed by Westcoast Transmission Co. Ltd.

[c]As proposed by Trans-Canada and Midwestern Gas Transmission Co. Ltd.

[d]As under construction by Trans-Canada.

[e]As built by Pacific Northwest.

[f]As built by Northern Natural Gas Co. Ltd.

[g]As completed by Tennessee Gas Transmission Co. and Niagara Gas Transmission Ltd.

words, in the 1960's and 1970's Canadian gas is likely to secure a return much more in line with its true competitive worth. Under these much more favourable circumstances a distinct and self-reliant natural gas industry is likely to achieve major status in this country.

The Pacific Northwest

Potentially, the Pacific Northwest is perhaps the best single outlet for Canada's surplus gas. Its energy requirements are continuing to mount at a rate well above the North American average. Other fuels are either relatively high in price or, over the long run, may be in short supply. Wood can be used to greater advantage in making paper pulps, building materials and other manufactured products. Coal resources are limited. California-produced oil, still the region's principal source of energy, is needed closer to home. Hence, it is with Alberta oil and water power produced on the Columbia River and its tributaries that natural gas will have to compete in Oregon, Washington and the Lower Mainland of B.C.

The region's energy consumption pattern has differed significantly from that of the rest of North America. For many years oil has provided about two-thirds of the total. The remaining one-third has been made up by coal, wood and hydro-electricity, more or less in equal proportions. Cord wood

and sawdust have been declining rapidly in importance while coal, having to be brought in by rail, has also lost many of its larger volume outlets in this area. The increased use of water power accounts for the difference.

In the initial stage, at least, natural gas is not expected to clash directly with electric power. Certain domestic demands—including water heating—may be intercepted. Also, less power will be used for space heating. But, measured in kilowatt-hours relative to total generation, its impact in the residential-commercial sector will be small.[9] Industrially, gas may mean more rather than less growth. Various enterprises may be encouraged to locate in the Pacific Northwest by the very availability of this new source of fuel and raw materials. Among them may be factories producing food products, pulp and paper, other wood products, primary metals, bulk fertilizers, other chemicals and building materials, particularly cement and brick. Indeed, such developments, together with the use interruptibly of gas for fueling thermal power plants, may augment rather than slow down the over-all demand for electricity in that region.

Competition from oil, on the other hand, may be much more vigorous. Fuel oil prices, in particular, may be reduced when natural gas is first offered for sale. Whether this situation will persist, however, depends upon (a) the trend in oil prices generally, in the United States (these may eventually move upward); and (b) the need for Canadian oil to capture a permanent market in California (this would have the opposite effect). On balance, quality considerations may have a greater effect than price upon the rate at which natural gas gains acceptance in the Pacific Northwest area.

More coal will be displaced by oil and natural gas. The greatest gain, *vis a vis* solid fuels, may, however, be achieved in competition with wood. The use of hogged wood wastes by the pulp and paper mills is already being reduced by the emergence of more remunerative uses for wood fibre than simply burning it as fuel. A number of larger mills—and this even includes a number of the lumber and plywood factories—may also become willing customers of the gas companies.

While most of these generalizations also apply to the lower mainland of British Columbia, they may be reinforced on the grounds that electricity is less firmly entrenched there. The markets presently served with manufactured gas made from coal will be taken over quickly. A number of industries, particularly those engaged in food processing and the manufacture of building materials, will begin to buy natural gas in volume as soon as it is available. Thereafter, sales for space heating purposes and to other industries

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[9]250,000 kilowatts has been mentioned as the possible equivalent in generating capacity of natural gas sold competitively with electricity during the first five years of service. This amount of power could easily be taken up by other industries, particularly those engaged in the manufacture of forest products or mineral processing.

will tend to move upward more slowly, one more or less in step with the other.

The following table gives some indication of over-all sales which may be achieved in the Pacific Northwest in the mid 1960's:

(billions of cubic feet a year)

Year	British Columbia	Washington-Oregon	Total
1965	60[a]	300	360

[a]Excluding, possible sales for metallurgical purposes at Trail, B.C. and for the generation of power in thermal plants.

Prairie Provinces

Sales of natural gas in western Canada are already in excess of 100 billion cubic feet a year. Having commenced much earlier in Alberta, they are still being made preponderantly in that province. Some 97 billion cubic feet were marketed there for residential, commercial, and industrial purposes in 1955.[10] In Saskatchewan, where natural gas service on any scale is a matter of only a few years' duration, annual consumption has recently passed the six billion cubic feet a year mark.

The volume of gas sold for non-field purposes has been growing rapidly. In Alberta, consumption, exclusive of exports, has trebled since 1945. Expressed in annual percentages this is the equivalent of a 12% rate. Even more impressive have been the gains made recently in Saskatchewan. Since 1953 when it was first introduced in volume into the city of Saskatoon a better than 50% saturation of the urban space heating market has been achieved.

Further requirements are difficult to anticipate. Supply will be no problem; this much is certain. The field price of natural gas will, however, move upward.[11] Rates charged to the customer, because of inflated construction costs, will tend to do likewise. Whether these forces will be sufficient to price natural gas out of some of its larger volume applications is, however, uncertain. With inflation the price of competing fuels will also rise. B.t.u. for B.t.u. gas may therefore continue to be a desirable source of energy. Furthermore, as wages edge upward, the fact that gas

[10]Total Alberta production, meanwhile, amounted to some 167 billion cubic feet. This can be broken down as follows: sales in Alberta, 97 billion; waste, 38 billion; exports to the U.S., 11 billion; storage, 7 billion; processing and otherwise used within the industry, 11 billion; and field applications used in connection with oil production, 4 billion. Sales in 1946 amounted to 30 billion cubic feet.

[11]The rate of escalation generally anticipated by the industry is in the order of one-quarter cent per M.c.f. per year or about 2.5% p.a. on the field price of raw natural gas.

can be used in equipment which is low in first cost and at the same time lends itself to automation is also in its favour.

Confirming evidence exists in postwar American experience. Except for transportation, natural gas is used to the virtual exclusion of oil and coal by most of the gas-producing states. In Texas, for example, demand has continued to rise at about 8% a year (*i.e.* doubling every nine years). This has happened despite a steady rise in field prices and a local abundance of other fossil fuels. Similar trends may be encountered in Alberta and Saskatchewan over the next decade. If they are the demand for natural gas will more than double by 1965.

Coal, it appears, will be displaced from most of its present applications. It may even have to share the thermal power market with natural gas. Peaking plants, and gas turbine installations may also require the use of natural gas as a fuel.

Vis a vis oil, natural gas may show a lesser relative gain. Yet experience elsewhere is illuminating. In such liquid fuel producing states as Texas and Oklahoma, products derived from crude oil have had difficulty in entering fuel markets other than transportation. They are used by the railways, on the highways and, to a much lesser extent, in agriculture. Otherwise, natural gas and its by-products—the natural gas liquids—have been looking, and will probably continue to look, after the majority of such regional energy requirements.

With these considerations in mind, provisional forecasts have been made, to 1965. In all cases these figures correspond roughly with those submitted to the Commission by the provincial authorities and by industry:

Sales in Billions of Cubic Feet

Year	Alberta	Saskatchewan	Manitoba	Total
1955	97	6	—	103
1965	235[a]	50[b]	15[c]	300

[a]The Alberta government submission suggests 150 billion in 1960 and 210 billion in 1970.

[b]The Saskatchewan government submission indicated a likely consumption of 33 billion cubic feet in 1965. However, no allowance was made for (a) sales to "large" industrial users, *i.e.* pulp mills, or (b) for purposes of generating electric power.

[c]The Manitoba government submission indicated a possible sale of 11 billion cubic feet in the fifth year of gas service, now expected to be 1962. Sales to large industry or for power generation could substantially increase this figure.

United States Mountain Area

An appreciable quantity of Alberta gas is now being marketed southward into the State of Montana. Now in excess of 10 billion cubic feet a year, it is expected to reach a total of 20 billion cubic feet annually by 1957 or 1958.

This market, which was first served from the Pakowki Lake area early in 1952, is an expanding one. The main reason for this is a diminution in local production in Montana and the western Dakotas. Indeed, were it not for supplementary supplies from western Canada, certain of the larger industrial consumers in Montana[12] would already have been forced to convert, at considerable expense, to the use of lignite coal or residual oil brought in by rail from mines and refineries hundreds of miles to the east.

The total market for natural gas (as served by the Montana Power Co.) was in the order of 31 billion cubic feet in 1955. Canadian exports in that year supplied one-third of the total—an amount about equal to the total volume purchased from all sources by the mining, metallurgical, chemical and cement companies in the United States Rocky Mountain and adjoining plains areas.

From now on, the use of Canadian gas is likely to be more general. Besides being sold to heavy industry at prices far below that of the other fuels available in this region,[13] it will also be made available for residential, commercial, and small industrial purposes. Load projections for the year 1960, for example, see gas from Canadian sources supplying well over half of all the gas delivered in this region. American production, meanwhile, will continue to run at a level well below the 28 billion cubic feet reported in 1950.

Sales in Billions of Cubic Feet per Year

Source	1950	1955	1960	1965
Canada	—	13	20	30
United States	28	20	20	20
Total	28	33	40	50

The United States Middle West

In the opinion of many oil and gas industry executives, the most logical eastward outlet for Canadian gas is the United States middle west. At least, they believe it to be a logical first stage market—one which could well

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[12]*i.e.* the Anaconda Copper smelter at Butte, American Smelting and Refining at Helena and several cement and chemical plants elsewhere in Montana.

[13]During the import hearings before the U.S. Federal Power Commission late in 1954, Mr. R. B. Caples, President of the Anaconda Aluminum Co. and engineering consultant for the Anaconda Copper Co., stated that the comparative costs of Canadian gas, oil and coal at Butte were, delivered, 20.5¢ M.c.f. for gas, 50¢ for heavy oil and 46.5¢ for coal in M.c.f. equivalent. Based on average fuel consumption over the previous 3 years, he stated, coal would have cost Anaconda $3 million more and oil $3.2 million more than gas from Canada.

Authorization for an import of 20 billion cubic feet annually of Canadian gas was extended to May 1974 by the U.S. Federal Power Commission in its ruling of May, 1955. The Canadian federal authorization, issued by the Department of Trade and Commerce extends for five years only. Then it will be up for renewal.

have been served prior to the construction of a line extending on to Southern Ontario and Quebec. Being cheaper to construct (and because most of the distribution outlets already exist), it would (with governmental approval in Canada and the United States) have been much more amenable to private financing.

In volume terms, the potential for growth is considerable. Already, sales in the general area embraced by the Dakotas and the states of Minnesota, Wisconsin and Iowa are in excess of 300 billion cubic feet annually. If the postwar record of the principal supplier, the Northern Natural Gas Co., can be taken as any guide, they are expanding at 13% a year rate. Performing a supplementary function at the outset, Canadian exports over the years may supply as much as half of these incremental demands. Exclusive of any allowance for supplementary sales in Michigan and Illinois, it is possible that sales of Canadian gas in this area of the United States might approach 150 billion cubic feet annually by 1965.

Price considerations, on the other hand, are less enticing. The net-back from the border price at Emerson, Manitoba, is well below that which could be recovered from sales to industry in Northern Ontario and Quebec.[14] It is probably less than that which could be obtained by exporting Canadian gas westward from southern Alberta directly into the United States Pacific Northwest.

Nor is this situation likely to change rapidly for the better. Many communities in the United States middle west have, for years, been receiving gas from United States sources. Much of this pipeline capacity (some of it built during the early 1930's) is already written off, and consequently, pays lower carrying charges than those which would have to be met by an entirely new line. Historically, the field price of this United States gas has also been low. Contracted at levels considerably less than those currently being asked, they have resulted in a city gates price structure which can only be revised upward with difficulty. Distributors and industries already served with natural gas, naturally enough, will resist this upward pressure on prices. Though theirs would be little more than a delaying action, they can, through the medium of the state and Federal Power Commission's hearings, render the middle west market less attractive to Canadian producers than it might otherwise be.

Western Canadian gas is, of course, being offered in competition with the latest reserve dedications in the mid-continent area of Kansas, Oklahoma and Texas. The majority of these are in the 15¢ to 25¢/M.c.f. bracket; that is, substantially above the 3¢ to 4¢ level which was common in the

[14]The starting large volume price to Trans-Canada at 95% load factor is 24.9¢/M.c.f. Over 25 years and allowing for price escalation it averages 27.5¢/M.c.f. Many large continuously operated industries in Ontario and Quebec pay more than 45¢/M.c.f. (equivalent) for their fuel.

major United States fields in the 1930's. For this reason, the Canadian producers can expect a higher return than would have been the case a decade or so ago. On the other hand, their gas must move farther to market. It must bear the full impact of present day financing and inflated construction costs. Also, being of a supplementary character, a higher proportion may have to be dedicated to the lower priced industrial outlets (*i.e.* power generation, iron ore beneficiation, steel production etc.). All these are reasons why sales of Canadian gas in the vicinity of Minneapolis-St. Paul may not be as attractive as geographical and other conditions might otherwise lead one to believe.

The following sales estimates are based upon the historical record pertaining to the United States middle west and to the optimistic projections of demand which have been made by the various utilities serving or proposing to serve this north central area of the United States:

Sales in Billions of Cubic Feet per Year

Source	1950	1955	1960	1965
Canada	—	—	70	140
United States	180	300	430	680
Total	180	300	500	820

Central Canada

By far the largest Canadian market for natural gas is that in Southern Ontario and Quebec. This central region now accounts for nearly 60% of the nation's total energy requirements. Excluding the transportation sector, it is currently the equivalent of some 1,500 billion cubic feet of natural gas annually.

Because the St. Lawrence Lowlands and their environs lack indigenous fuel resources and because both coal and oil must be imported over considerable distances, their laid down cost of energy tends to be relatively high. This, together with the increasing concentration of the secondary and service industries in this part of the country is the main reason why this central region is bound, in time, to provide an attractive outlet for western Canadian production.

Several obstacles have to be overcome. Manufactured gas has never been sold in anything like comparable volume. Suitable distributing facilities have, therefore, to be created *de nouveau* and customers, particularly in the residential and commercial categories, educated to the advantages of using a fuel, the properties of which (outside the southwestern tip of Ontario) are practically unknown. An immediate market in what is generally regarded as being the premium use category is, therefore, lacking. Special measures are obviously called for if Ontario and Quebec are to warrant the attention which their economic potential so patently deserves.

One necessity is a departure from tradition—namely the market building sequence so commonly followed in the United States. The pipeline promoters there are accustomed to pushing lines into areas where the direct conversion from manufactured gas assured them of a quick return on investment. They have, at the same time, been carrying natural gas into comparatively low-cost energy regions where only space heating and a few other high grade applications really warranted the introduction of this new fuel. Sales to industry, meanwhile, have been tolerated as a necessary evil. By helping to iron out seasonal fluctuations in demand, they help to meet carrying charges and, hence, to minimize transportation costs. Gas sold customarily for load balancing purposes has frequently had to be disposed of on a near-to-dump basis.

In much of central Canada, industry is accustomed to paying much higher prices for its fuel; many of the larger Canadian users, such as the pulp and paper mills and metallurgical plants, are prepared to take natural gas at a price approaching, if not as high as prices currently being quoted to the large distributing utilities in cities like Toronto and Hamilton. These large volume markets, furthermore, are immediately available. They can be connected at a comparatively high load factor, thus assuring more effective utilization of main line capacity. If necessary, they can also be contracted over long periods of time. Such considerations, while they were not fully appreciated when the first efforts were made to finance the Trans-Canada gas pipeline, can and undoubtedly will, provide a substantial source of revenue in the future.

The following market estimates, while they have been made independently, assume that the Trans-Canada pipeline project, as presently envisaged, will be operating at or close to capacity by 1965. Also, that appreciable quantities of United States gas will continue to enter Southern Ontario both at Windsor and Niagara:[15]

Sales in Billions of Cubic Feet per Year

Year	Ontario	Quebec	Total
1955	20	—	20
1965	160	40	200

1980

Looking ahead even further, to 1980, presents problems of its own. Increased volumes of Canadian gas will, undoubtedly, be sold both in this country and in the United States. Throughout western Canada, demand may continue to rise at a rate appreciably above that recorded, historically,

[15]*i.e.* some part of the presently contracted 22 billion cubic feet/year presently scheduled to arrive over Trans-Canada's connection at Niagara and 21 billion cubic feet/year over the Union Gas Co. connection at Windsor.

in the United States. In Ontario and Quebec, on the other hand, sales will depend much more upon policy decisions. Transportation costs can be minimized through the use of larger diameter pipe, load balancing with the aid of interruptible sales to heavy industry and by delivering off peak gas into underground storage facilities in Southern Ontario.[16] Canadian outlets in British Columbia, the eastern Prairie, and central Canada must also be viewed in their true geographical perspective. Each can benefit by a substantial volume of exports through and beyond their own sales territories. Thus, a pipeline destined to serve northern California would help to stabilize prices in British Columbia. The same would be true *vis a vis* Winnipeg with respect to one or more projects built to serve such eastern centres as Chicago and Detroit. Southern Ontario, in particular, would also benefit from a spill-over export arrangement whereby Canadian gas was marketed at the end of a series of long lines, whose throughput was intended for consumption in New York and the New England states. All these are possibilities, the majority of which may be realized well before 1980.

For purposes of estimating the potential Canadian demand 25 years hence, the regional requirements for 1965 were projected a further 15 years at varying rates. Those chosen for British Columbia, Alberta, Saskatchewan and Manitoba were 10%; 8%; 10%; and 11% respectively. Due to its comparatively small contribution, even in 1965, gas markets in Ontario and Quebec were also taken to increase at an 8% rate (*i.e.* doubling every nine years) during the remainder of the 25-year period under review.

When combined, these results suggest that the demand for natural gas in Canada by 1980 may have reached two trillion cubic feet per year.

A check on the validity of such an annual figure can be obtained by expressing the consumption rate in per capita terms and comparing it with the per capita consumption rate in the United States. The present level of consumption in Canada is of the order of 10,000 cu. ft. per person—a figure reached in the United States about 30 years ago. Meanwhile, in that country, this figure had increased to 20,000 cu. ft. per capita by 1940; 33,000 cu. ft. per capita by 1948 and a phenomenal increase to 50,000 cu. ft. per person by 1955. On the basis of our expectations for Canadian consumption by 1980—two trillion cu. ft.—per capita consumption in this country will then be approximately 75,000 cu. ft., a figure that should then be more in line with United States per capita consumption, which is expected to double over the quarter century to 100,000 cu. ft.

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[16]The relative carrying capacities of a 24-inch, 30-inch, and 36-inch diameter line are in the order of one to one and one half to two and one quarter. Their capital cost, on the other hand, varies in the ratios of 100: 120: 135.

The capacity of the presently proven and probable gas storage fields in Southern Ontario is in the vicinity of 100 billion cubic feet or about one-half of the ultimate annual throughput of a 30-inch line.

By following an international routing the cost of transporting natural gas to Eastern Canada could be reduced by at least 10% or around 4¢/M.c.f.

In what follows, an attempt has been made to quantify Canada's export possibilities. These, it appears, are considerable. Potential markets in adjoining areas of the United States will doubtless exceed Canada's ability to serve them. Assuming, however, that supplies were readily forthcoming, sales of as much as 3,000 billion or even 4,000 billion (three trillion or even four trillion) cu. ft. might be made annually to the United States in 1980. On the other hand, considerations as to availability, the price which can be obtained for gas outside Canada, and the policies followed by both the provincial and federal governments with a view to safeguarding further domestic requirements, will also have an important influence on the amount of Canadian gas actually allocated for this purpose.

In this study, it has been assumed, quite arbitrarily, that exports will amount to 1,000 billion (one trillion) cubic feet of gas annually in 1980. The amount of gas sold in the United States, in other words, might be about half of that employed in this country. Thus it envisages four or five projects equivalent in capacity to the Westcoast Transmission line actively supplying natural gas to the United States 25 years from now.

Section IV: Supply-Demand Trends, 1955-80

For purposes of quantifying the impact of natural gas on the Canadian economy, it has been necessary to make a number of assumptions—assumptions which appear reasonable in the light of past experience, and yet assumptions which could, and indeed may, be invalidated with the passage of time.

One reason for this apparent humility is the relative newness of large-scale natural gas production and marketing in this country. Another relates to government policy. Should one or more of the provinces in which the gas occurs, or the government in Ottawa, or both, see fit to set aside a large proven reserve against future domestic requirements, the incentive to look for additional supplies will be reduced. At the same time, the search for oil in particular will continue to be rewarding. Also, the results of future exploration and development may be such as to disallow any lasting concern as to the adequacy of Canadian resources. Should the latter happen—and many geologists think it will—then this country may well be exporting as much gas to the United States as it consumes 20 to 30 years from now.

In launching such an exercise—it is no more than that—method is important. Various projections must be made. Based on a variety of data—some of which pertain to other countries, particularly the United States—they differ very much as to quality. Starting from a few which are anchored more reliably to recent Canadian experience and proceeding sequentially to those which are at once more descriptive (one might even say more imaginative) in character, we have attempted to trace the orders of magnitude which may be encountered in the production, consumption and

export of Canadian natural gas over the next quarter century. (See chart: Natural Gas Consumption in Canada—1926-1980.)

The logical starting point is a considered projection of Canadian reserves. Canadian requirements, both in the vicinity of the gas fields and elsewhere across the country, must then be assessed, these requirements having the first priority in use. Finally, an attempt can be made to determine the quantity of surplus gas available for export to adjoining areas of the United States. (See chart: Inter-Regional Movements of Natural Gas 1960 and Potential Markets For Canadian Gas 1980.)

The results of such an exercise are, necessarily, subject to revision. They give no more than a first approximation in that the reverse procedure—namely, of proceeding from an assessment of potential export demand back to a responding proving up of reserves—might have comparable, if not equal, validity.

Our analytical procedure therefore tends to be circuitous in character. Necessarily so, for the nation's proven reserves of natural gas will certainly be affected, if not directly determined, by the industry's near term expectations as to the marketability of its product. An easy-going policy with regard to gas exports, combined with a steadily mounting gas deficiency in the United States would, doubtless, turn up more proven reserves in any given ten-year period, than would a more conservative policy designed to protect the longer-term needs of Canadian users. Thus, as in our analysis of the energy market in general, we have been faced with the need of proceeding from supply to demand and back again several times before arriving at a general conclusion as to the possible course of events between now and 1980.

In doing this the detailed procedure has been somewhat as follows:

(1) The natural gas reserve figures have been derived essentially from our expectations as to oil discoveries. Four thousand cubic feet a barrel was assumed to apply in instances where there was little or no incentive to look for gas. Six thousand cubic feet a barrel on the other hand was assumed to be the maximum, regardless of the dictates of the market.[17] Thus the search for oil, resulting in a 25 million barrel petroleum reserve would turn up at least 100 billion cubic feet of natural gas. With an adequate market incentive this amount might be increased by about 50% or to around 150 billion cubic feet.

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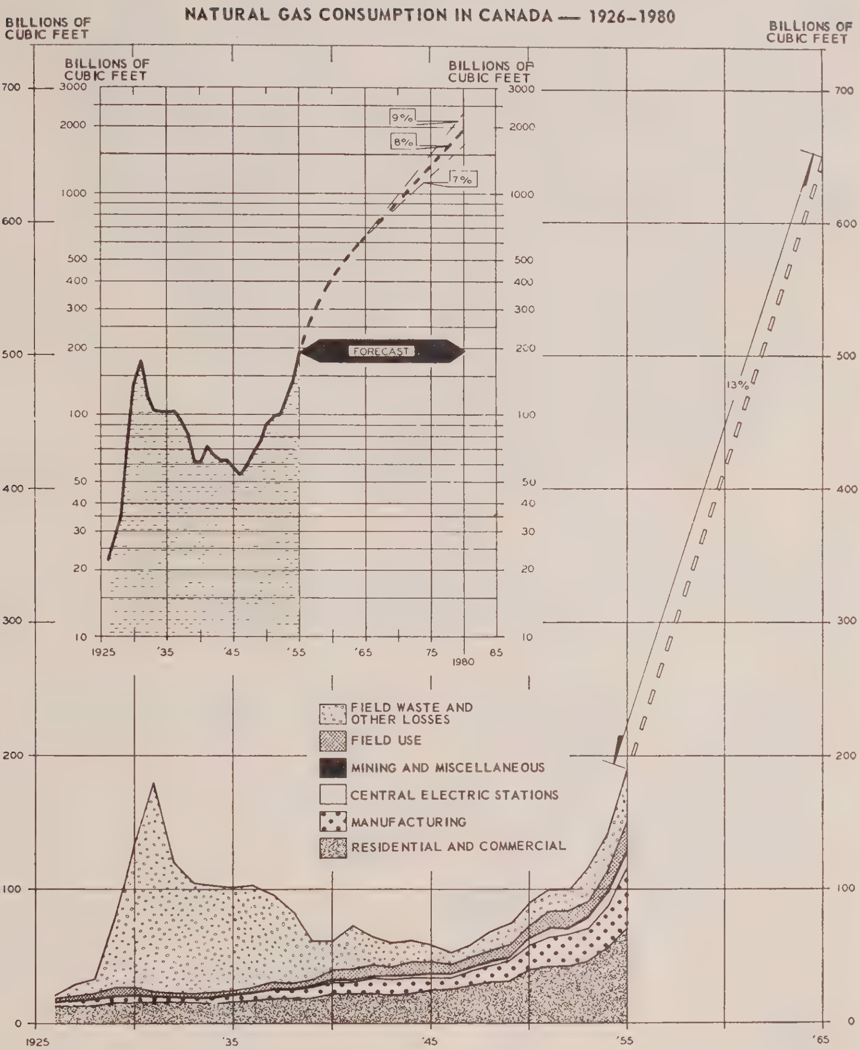
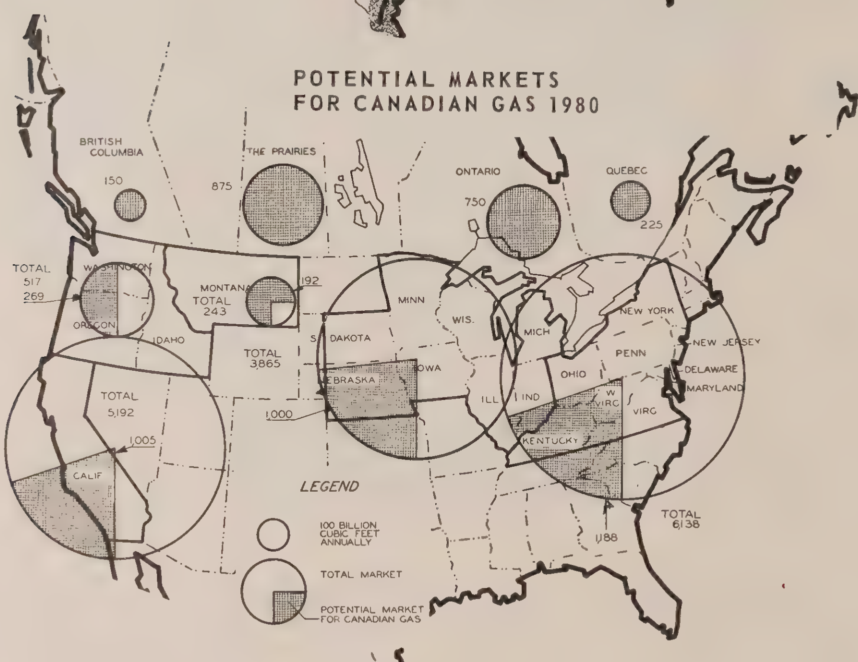
[17]The well known United States geologist, Mr. Wallace E. Pratt, in reporting to the U.S. Joint Congressional Committee on Atomic Energy early in 1956, reported that the intimate association of oil and natural gas in their natural occurrence has resulted in the United States in the past discovery—largely incidental to the search for oil—of about 4,000 to 5,000 cu. ft. of natural gas for every barrel of oil discovered. He also said that, in recent years, this ratio had risen to some 6,000 to 7,000 cu. ft. and inferred that a further improvement in this ratio might, indeed, take place. (Six thousand cu. ft. of natural gas is roughly equivalent in energy content to one barrel of oil.)


NATURAL GAS CONSUMPTION IN CANADA — 1926–1980
BILLIONS OF CUBIC FEET
BILLIONS OF CUBIC FEET
9%
8%
7%
FORECAST
13%
FIELD WASTE AND OTHER LOSSES
FIELD USE
MINING AND MISCELLANEOUS
CENTRAL ELECTRIC STATIONS
MANUFACTURING
RESIDENTIAL AND COMMERCIAL
1925
'35
'45
'55
'65
75
85
1980


INTER-REGIONAL MOVEMENTS
OF NATURAL GAS 1960
SOURCE AREA


POTENTIAL MARKETS
FOR CANADIAN GAS 1980
BRITISH COLUMBIA
150
THE PRAIRIES
875
ONTARIO
750
QUEBEC
225
TOTAL
517
269
WASHINGTON
OREGON
MONTANA
TOTAL
243
192
IDAHO
MINN
WIS.
S. DAKOTA
TOTAL
3,865
IOWA
NEBRASKA
1,000
ILL
IND
MICH
OHIO
NEW YORK
PENN
NEW JERSEY
DELAWARE
MARYLAND
W VIRG
VIRG
KENTUCKY
TOTAL
5,192
1,005
CALIF
LEGEND
100 BILLION CUBIC FEET ANNUALLY
TOTAL MARKET
POTENTIAL MARKET FOR CANADIAN GAS
1,188
TOTAL
6,138

(2) The next step was to assess future Canadian requirements. As described at the end of the previous section, these may rise approximately tenfold to around two trillion cubic feet in 1980. At the end of any given year reserves arbitrarily set aside to back up these mounting requirements were sufficient to meet a 4% per annum rate of growth in demand over a further 25-year period.

(3) Existing and immediately foreseeable export commitments were then appraised. Assumed to continue at full pipeline capacity over 25 years, they were given, what amounted to a second priority claim on established Canadian resources. Cumulative production for sale in Canada or exported under this heading might amount to some 30 trillion cubic feet by 1980.

(4) There followed a determination, by difference, of the amount of oil search associated gas left unallocated either to Canadian consumers or to presently envisaged export projects. This quantity, as it turned out, was sufficient to support more than one major pipeline promotion. From then on our efforts were bent on finding an answer to the question, "How many more can be justified"?

(5) It was necessary, having reached this point, to turn to the foreign demand side. Starting from historical data, market forecasts were prepared state by state for the major United States gas consuming regions within a 2,000 mile radius of southern Alberta.

Again, it was necessary to make concise judgments. In doing this it was assumed that Canadian natural gas would be in demand to the extent of some two-thirds of the growth requirements of United States Pacific Northwest after 1958 (*i.e.* Washington, Oregon, and Idaho); all of the supplementary requirements of the State of Montana after 1955; one-third of the incremental demands of the midwestern States (*i.e.* the Dakotas, Minnesota, Wisconsin, Iowa and Michigan) after 1960; one-quarter of the growth requirements of the northeastern States (*i.e.* Ohio, northern New York and New England) after 1965; and one-quarter of the growth requirements of California after 1965.

When added up these turned out to be a substantial volume—some 3.5 trillion cubic feet a year by 1980. Backed up by a 25-year reserve they, together with prospective Canadian needs, point to an order of magnitude far larger than the amount of gas likely to be forthcoming merely as a by-product of the search for oil. Such an incentive, were it backed up by an easy going export policy on the part of Canada would result in a near to maximum gas-to-oil ratio. Instead of being of the order of 4,000 cubic feet for every barrel of oil found it might rise to, or even exceed, the 6,000 to one ratio mentioned previously.

These calculations lead to several interesting conclusions. They show:

(a) that without any incentive to look for natural gas as such sufficient supplies to meet Canada's foreseeable (25-year) requirements will be forthcoming;

(b) that the amount of gas *produced* along with oil (about 500 cubic feet per barrel) will, after 1970, be less than that required to service the domestic market;

(c) that a volume of gas in excess of one trillion cubic feet annually cannot be committed on long-term markets in the United States without endangering the Canadian supply position after 1980; and that

(d) the actual gas reserve position in any year will both influence and, at the same time, result from policy decisions taken as to the exportation of Canadian gas.

Timing is of course important. However, it would appear that four or five projects similar to the present Westcoast promotion might be approved over the next 25 years without necessarily reducing the amount or unduly raising the price of Canadian gas available for home consumption. Exports amounting to around one trillion cubic feet annually have therefore been assumed as selling in the United States Pacific Northwest and California, middlewest, north and eastern states a quarter century from now.

The following table presents in summary fashion certain of the assumptions and results of these exploratory calculations.

(trillion cu. ft.)

Year	Virgin marketable reserves	Annual marketed production	Cumulative marketed production	Remaining reserves	Life index in years A[a]	Life index in years B[b]
1955	20	.17	.17	19.8	117	12
1965	48	.85	5.0	43.0	60	—
1980	100-150	3.00	30	70-120	23-40	11-19

[a]Simply remaining year end reserves divided by the then annual rate of production.
[b]Allowing for a continuing Canadian market growth of 10% per annum to 1980 and 4% thereafter. Canadian requirements, unlike exports, are assumed to require a larger reserve to allow for continued (minimum) growth.

Section V: Financing of Development

Until recently the amount of money being invested in the search for natural gas, in its processing, and in pipelines and local distribution systems was comparatively modest. Annual outlays, including exploration development as well as the purchase of machinery and equipment, rarely exceeded $10 million. Since 1952, and reflecting a growing interest in the

possibility of exporting western Canadian gas, the industry's financial commitments have risen sharply. Capital outlays, swollen by the laying of the Westcoast and initial stages of the Trans-Canada main lines, resulted in better than a $150 million expenditure in 1956. Though the oil companies are collectively still spending between three and four times as much, natural gas is rapidly gaining recognition as a separate Canadian industry with major projects, problems and a corporate character of its own.

In the late 1960's and 1970's several hundreds of millions of dollars will have to be found year in and year out for purposes of expansion. This is a large amount of money. Its magnitude raises the question as to whether the majority of the funds necessary for the execution of this programme will (or indeed can) be raised in Canada. There will be no lack of interest elsewhere. Large corporations with considerable experience in all phases of the natural gas industry will be vying with each other for control of Canadian reserves and pipeline franchises. Whether Canadians will gain the experience necessary for them to be able to play a dominant role in financing these developments is more a matter of conjecture.

The oil industry, as now, will continue to turn up much of the gas. Some two-thirds of Canada's reserves will probably be found as a by-product of the search for oil. Much of our future supply, in other words, will be proven up without capital ever having to be raised specifically for this purpose.

Whether or not the oil companies will wish to retain title to their dry gas resources is something else again. Often in attempting to avoid the government and other restrictions normally placed upon utility type industries, they have followed the practice of selling off their gas reserves. These, together with single well dry gas discoveries, have often been taken up by the major gas transmission line companies or, when nearby markets are available, by the local distributor. Some gas, being intimately associated, will have to be produced along with the crude petroleum. This the oil companies will use for their own field purposes or sell, as it is produced, to the pipeline franchise holder enjoying the exclusive right to move natural gas out of the producing area in question.

While the oil industry will find most of the gas, the continent's major gas transporting companies, often through corporately related concerns, will also spend a good deal of money on exploration and development. One of the reasons for their expected prominence is geographical. Canada's greatest gas potential lies in the foothills region of the Rocky Mountains. Here, because of the great depths of sediments involved, exploratory drilling is expensive. Yet the results for those who can plan on an appropriate scale will be rewarding. Established market connections or a long record of pipeline experience helps in raising the necessary funds. Lacking these capabilities it is doubtful whether many small or independent Canadian companies can

participate in this play. Thus, it is the larger gas transporting and distributing companies that Canadians may have to turn for the funds (or for the contracts pre-requisite to the raising of funds) needed to develop gas reserves independently of the search for oil.

Rarely is pipeline financing difficult—at least, when the resources are formally dedicated, the markets contracted and the route officially approved as both economic and necessary. Having contracted its gas supplies and secured sufficient markets to operate its facilities at 70% or more of capacity, the promotional interests have one more major hurdle to surmount; that of obtaining the approval of the appropriate governmental authorities. In respect to interprovincial movements those of the provinces and the federal government are involved. In the case of an export project, these intentions must also be examined by and found acceptable to the United States Federal Power Commission. Having passed this scrutiny, the raising of money is easy. Larger bank loans are available when the necessary approvals have been granted. Half or more of the capital can be raised by sale of comparatively low interest bearing bonds.[18] The remainder, beyond that put up initially by the promoters, can be covered through the issuance of common and preferred stock.

In recent years there has been a pronounced shift in the percentage distribution of the various types of securities held by the natural gas transporting companies. In the United States as late as 1939, long-term debt (bonds) accounted for around 40%, preferred stock for around 10% and common stock for about 50% of all the securities issued by the mainline transmission companies. In the intervening years the gas business has become much more respectable. Gas has gained recognition as a valuable commodity. The binding nature of the long-term supply and market contracts has also been confirmed. Hence the insurance companies and banks are much more willing to lend money to projects of this kind. (See chart: Gas Company New Security Issues U.S.)

As a result, some of the latest projects are being floated with common stock contributions as low as 10%. Few offer common ownership stock in excess of 20% of the capital cost of their project.[19] In parlance more familiar to financial circles, its leverage is high; higher even than is the case with the older and better known electric power utilities. Since rates (and therefore earnings) are determined on the basis of capital invested and the allowed return as measured in this way may be in the order of

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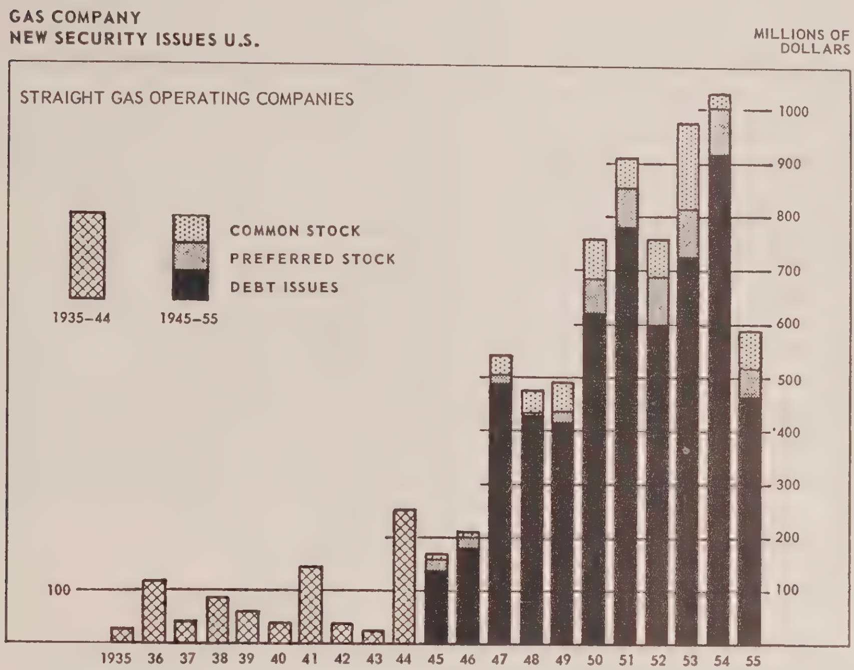
[18]Trans-Canada Pipe Lines Ltd., 57% (excluding the publicly built section of the line which the company has a right to purchase out of retained earnings); Westcoast, 54%; and Pacific Northwest 57% mortgage bonds.

[19]Composite data for *all* U.S. transporting companies (old and new) as reported in the American Gas Association publication, *Gas Facts,* show long term debt to be 70% of total plant less depreciation, and preferred stock to be about 8%. Trans-Canada Pipe Lines common stock to total investment ratio is about 19%; Westcoast, 12%.

7%, the return on pipeline equity capital after a few years may be several times this percentage. No wonder that government franchises in the gas line business are so eagerly sought or that the legal battles involved in their granting are so bitterly contested.



To the extent that Canadian gas is exported to the United States it is likely that the pipelines involved will be owned and controlled by United States corporations. Westcoast Transmission Company is preponderantly owned in the United States. The Trans-Canada Company, directly and indirectly, may be also. One of the reasons for this is the securing of sales contracts. Deals must be made with the major United States franchise holders. If they have not conceived and organized the project from the outset they may still demand a measure of control as their price for co-operating in the venture. Hence it is only in respect to shorter lines destined primarily to serve Canadian consumers that a goodly measure of Canadian participation may be envisaged.

Substantial amounts of money will also have to be invested in the re-furbishing and expansion of local distributing facilities in this country. Long-established manufactured gas systems are being taken over along with the municipal franchises. Much of this plant may be useless. Sometimes the lines themselves are incapable of handling a drier product at higher pressure. Their carrying capacity certainly will have to be augmented if not replaced. Hence the distributors may have to invest as much, dollar for dollar, as the

mainline supply companies. That the necessary funds may be forth-coming can be judged from American experience. Few distributors faced with a major conversion programme or starting afresh have lost money for more than a few years. The majority, and particularly those which have priced their gas with the intention of developing a large-volume business have earned handsome profits in a comparatively short time.

Corporately, the Canadian pattern is already being set in this direction as well. Ownership of some of the older utilities in Canada's largest cities has recently changed hands. Elsewhere exclusive franchise rights are being sought eagerly—usually by American-backed companies with considerable experience in the distribution end of the business. United States consulting firms have been engaged both to make market appraisals and to carry out the conversion of systems from manufactured to natural gas. As a result of these activities it would appear that the marketing phase of the natural gas industry will remain substantially in Canadian hands in Southern Ontario, in Saskatchewan and on the west coast of British Columbia. In Alberta, Manitoba, Northern Ontario and Quebec, United States interests will have a major hand in, if not enjoy a majority control over, these activities. Because of the adequacy of supply, competitive price offerings and the financial rewards already being reaped elsewhere, these corporations should encounter little difficulty in raising the capital necessary to complete the expanding distribution programmes which they have in mind.

Supplementary Note:

The natural gas industry is *not* characterized *by the same degree of integration* as is the case of oil. While the main line transmission companies frequently own substantial gas reserves and operate their own gas cleaning plants, they usually concentrate their attention upon maximizing their returns from long distance transportation. Subject to a much greater degree of government regulation and at the same time protected by their long-term supply and user contracts, their operations, as well as their methods of raising money, tend to resemble those of the electric power and other public service utilities.

No mention has been made here of the economic implications of the United States transportation utilities buying into the major Canadian gas line promotions. In all cases to date the purchaser at the border owns common stock in the Canadian line. In the case of Canadian-Montana, the American company owns 100%. Pacific Northwest owns 25% of Westcoast's common stock. Tennessee Transmission owns stock and had a major say in the pricing of Trans-Canada gas south of Winnipeg to its subsidiary, Mid-Western. These customer companies, because of their corporate ties, have exerted (and may well continue to exert) considerable influence upon the pricing and other policies followed by their subsidiary and other supplier companies in Canada.

Section VI: Effect on Other Fuel Supplying Industries

Natural gas, as it begins to be sold in volume across Canada, will affect the other fuel supplying industries in various ways. Competitive conditions similar to those which have been experienced in the United States since the late 1930's will be encountered. A review of recent happenings in the United States can therefore provide some insight into the effects which the growth of this new industry will have on the petroleum, coal and manufactured gas industries in Canada between now and 1980.

Petroleum

The petroleum and natural gas industries—still often regarded as one and the same thing—are now tending to tread separate paths. Expanding markets and increased field prices have encouraged the search for natural gas as such. Also the oil companies, in attempting to avoid the degree of government regulation common in the utility field, have generally followed a policy of auctioning off their gas discoveries to companies engaged exclusively in its transportation and distribution. Corporate entities therefore have emerged which tend to resemble much more those engaged in the generation, transmission and sale of electric power.

To the extent that by-product gas can be sold in volume and at attractive prices, the oil companies are able to secure additional revenue. Without a ready market for natural gas they would otherwise have to resort to the expensive process of recycling or pumping their by-product gas back into the oil productive formations once again. Another reason for the oil industry's comparative neutrality is that the sale of natural gas frequently supplements rather than takes outlets away from the more highly processed oil refinery products. Transportation, regardless of type, is the greatest single user of liquid fuels. Natural gas cannot readily be used to power motor vehicles, aircraft, ships and railway locomotives. Hence it does not compete directly with gasoline; infrequently with diesel oil. As far as the heavier fuel oils are concerned, displacement, while it occurs, is frequently on a seasonal or short-term basis.

Natural gas has made its greatest inroads on the lighter grades of fuel oil. These are the middle distillates which are used primarily for space heating. In Canadian circumstances, climatic conditions must also be taken into account. Because of the exceptional midwinter peaks in demand, the oil refineries find it necessary to import a sizable proportion of the nation's requirements. This they find more economic than erecting additional storage capacity. With the arrival of natural gas this need to rely on external sources of crude oil products supply will be reduced.

There will, of course, be instances in which heavy industry in contracting for natural gas on an interruptible basis will take less residual oil. Competition of this kind is not likely to be serious however. The petroleum refineries

can always obtain alternative outlets by reducing prices. Later as new refinery capacity is erected they will probably convert more of these lower priced oil fractions into higher priced and more salable petroleum products.

Coal

The arrival of natural gas will be felt most by the coal industry. Not only will natural gas be preferred for space heating purposes but it will also reduce the demand for other industrial fuel in the summer-time.

There are exceptions of course. Large steam plants, particularly those at a distance from the gas fields, will continue to use coal for the generation of electricity. In this they will be motivated by the lower cost per B.t.u. of the coal laid down in their yards. Thermal generating stations such as those which are being built in Southern Ontario, since they can be supplied much more cheaply from nearby coalfields in the United States, will therefore have little incentive to use natural gas which has been transported all the way from western Canada.

While the impact from the coal industry will tend to be selective and vary according to location, the net effect will be to reduce, or at least minimize, imports. Many industries in Ontario and Quebec which have previously had to choose between residual oil and United States coal have continued to use the latter. Natural gas, to the extent that it continues to be sold at lower than average prices and essentially for line load balancing purposes, will however cut into coal's larger volume markets.

Manufactured Gas

The volume of natural gas now sold in North America is about ten times that marketed in the manufactured or artificial gas form. The disparity between the two, furthermore, is increasing year by year.

This is due partly to the difference in application. Whereas fully two-thirds of all the manufactured gas is consumed by household users, the largest amounts of natural gas are sold for industrial purposes. Manufactured gas prices are less controllable in that they are dependent to a large extent upon those of coal and oil. Again, the natural product has roughly twice the energy content per cubic foot of that of manufactured gas. Substitution, one for the other, virtually doubles the energy carrying capacity of existing facilities. A switch all the way to natural gas therefore does two things: (a) it eliminates the need for building new manufacturing plant and (b) it allows existing systems to substantially increase their volume of sales without having to make a commensurate investment in pipe and other distributing facilities.

Of even greater importance is the fact that natural gas can be sold profitably at prices well below that of the artificial product. Within a few

years of its introduction it is usually offered at between one-third and one-half of the price of the coal or oil based fuel. This, together with much greater predictability of costs, is among the reasons why many industrial and commercial users which have shown little interest in using the manufactured product are signing contracts for natural gas extending 10 and sometimes 20 years into the future.

Section VII: Natural Gas Liquids[20]

Summarily described, the natural gas liquids might be termed by-products of a by-product. Wet constituents of natural gas as it comes from the gas in the ground, they must necessarily be drawn off in the ensuing clean-up procedure. Once flared at the field or sold simply for their natural gasoline content, they have recently begun to come into their own. Sales have tripled in North America over the past decade. With demand expanding even more rapidly than that of natural gas,[21] the transportation and marketing phases of this allied industry appear to be in for a remarkable era of growth.

Improved conservation practice has been one of the causes. The law of most gas-producing states and of western Canadian provinces now requires that these fuels either be put to effective use or be returned to the underground reservoirs from whence they came. Better recovery methods have been instituted. Thus, with the passing years, the ratio of natural gas liquids to dry gas sales has been rising. Improved techniques and equipment have helped to overcome such problems as inflammability. Also, new uses are continually being developed and old ones expanded. These are among the reasons why natural gas liquids are expected to make a significant, if not major, contribution to the nation's energy supply pattern in the 1960's and 1970's.

As in the United States, there will be a tendency to over-production. Prices at the field will, therefore, remain low. Supply, rising along with, or even faster than, natural gas production will be locally out of phase with the demand for oil. That portion which can be sold as natural gasoline or blended with other products at the oil refineries may encounter fewer difficulties. However, much of the remaining propane and butane—being in excess of western Canadian requirements—may have to be stored pending the development of more distant markets in eastern Canada, adjoining areas of the United States or overseas.

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[20]Natural gas liquids include propane, butanes and natural gasoline. The term l.p.g.'s, or liquefied petroleum gases, refers to propane and butanes. In the United States, about 25% of the l.p.g. production comes from petroleum refineries and 75% from gas processing plants in the field; in Canada production is 50% from refineries and 50% from field plants.

[21]Total value of sales of natural gas liquids in the U.S. is now commensurate with that of marketed clean dry gas production.

Only the roughest of approximations can be made as to future supplies. The amount recovered will vary from reservoir to reservoir. It may range, as in the United States, from 10 to 75 barrels per million cubic feet of natural gas. Canadian experience to date has been in the order of 27 barrels per million cubic feet processed. Possibly this is on the low side. As the search for liquid fuels pushes westward into the foothills and northward into the Peace River District, this ratio will tend to rise. Production in the order of 35 barrels per million cubic feet may therefore be encountered by 1980.

The following tabulation, based on the expected natural gas discoveries mentioned earlier in this study, gives some indication of the quantities of this fuel which may be available for Canadian consumption or export, 10 and 25 years from now:

	1955	1965	1980
Reserves in millions of bbls.	250	800	4,000

In assessing the outlook for propane and butane in western Canada, marketing trends for these products in the United States can be used as a guide. Sales in 1925 totalled only one-third of a million gallons. By 1944, they had risen to one billion gallons and, in 1955, to five billion gallons. Thus, in 30 years, they have shown a 15,000-fold increase. During the past decade, the average annual increase in marketed production has been in the order of 17%.

As in western Canada today, one of the main problems has been transportation. Tank trucks are commonly employed in the serving of nearby customers. Railway tank cars still carry some two-thirds of all the natural gas liquids sold at a distance from the fields. Both of these are expensive methods when large volumes and long distances are involved. Pipelines, first introduced in the United States in the 1930's may, consequently, find greater use in western Canada. Laid in the same trench as the larger gas lines and selling their throughput more to supplement rather than in direct competition with natural gas, they may soon make possible the tapping of markets 1,000 to 1,500 miles distant from the main producing areas of Alberta and northeastern British Columbia.

The development of terminal underground storage will be of considerable help in this regard. Since the principal market for propane will continue to be space heating, some such outlet will have to be found for summer movements if efficient pipeline operations are to be envisaged. Once achieved, however, there is little to prevent these liquids reaching out across the continent much as natural gas has done to areas which formerly were heavily dependent upon solid fuels or oil refinery products.

Waterborne shipments must also be envisaged. Already, a fair volume is moving northward in the United States by barge. One or two tankers are

already in operation and others are being built to serve such faraway markets as the New England states, Eastern Canada, and Western Europe. For example, appreciable quantities of natural gas liquids produced in the United States were sold in the Maritimes, Quebec, England and the Scandinavian countries in 1955. With this happening, exports by tanker from Canada's west coast or down across the Great Lakes must also be kept in mind as possibilities for the future.

In western Canada the industry is in its comparative infancy. Recovery of natural gasolines from "wet" natural gas commenced in the early Turner Valley days, but it was not until 1948 that propane and butane were produced in specially-designed processing plants. Since then, their production from field plants has risen rapidly, output in 1955 totalling some 45 million gallons. Practically all of this output is being sold in Alberta and in adjoining areas of British Columbia and Saskatchewan.[22] In the present early stages of this industry storage problems present serious obstacles to the co-ordination of production and market growth.

While markets have been found for all of this new production, the problem of future surpluses, contingent on much greater gas production, has yet to be faced. Some 1.5 million people living in the western provinces are beyond the economic reach of natural gas pipeline distribution systems. Many of these can be expected to buy propane for space heating and other household purposes. Those on farms may also employ the natural gas liquids for driving tractors, irrigation pumps, and other mechanical equipment. Less than 10% of such customers in these rural areas do so at the present time. This, then, is the first and possibly largest single outlet for this Canadian-produced fuel.

More of these liquids may also be sold for use in internal combustion engines. An excellent fuel for heavy trucks, buses, drilling engines, etc., the passing years may see them cutting into a market for refinery gasolines and diesel oil. Establishment of a network of special filling stations could also induce many operators of the lighter commercial vehicles to make this change. The railways, too, may be able to take advantage of local surpluses. Using gas turbine-driven locomotives, they would thereby benefit from lower fuel and engine maintenance costs.

In industry, the liquefied petroleum gases can be used for many of the same applications as natural gas, including metal cutting, brazing and otherwise heat treating metals, carbonizing steel, glass processing, brick making and for general process and space heating in numerous manufacturing enterprises. As raw materials they are ideal for the production of a variety of petrochemicals. This is particularly true of alcohols, acetates,

[22] In addition petroleum refinery output in 1955 was in the order of 65 million gallons. This was valued at approximately 11¢ a gallon at Canadian oil refineries, whereas the value placed on Alberta natural gas plant production was about 4¢ a gallon.

detergents, plastics, organic acids, glycols and resins. More and more butane will be converted into butadiene which is an important raw material for synthetic rubber production.

These are interesting possibilities. However, such outlets as are available to Canadian producers may be largely restricted to the domestic market. In entering the United States one obstacle which they have to surmount is a tariff identical to that on crude petroleum, namely 10.5¢ a barrel. Were this to be removed one could expect an appreciable movement of these products into the United States Pacific Northwest from Alberta and British Columbia. Exports in this direction, thus, could help to offset imports being brought into the Atlantic region and central provinces. At the present time shipments from the United States into Ontario, Quebec, the Maritimes and Newfoundland are in the vicinity of 40 million gallons annually.

Still under investigation is the possibility of transporting by pipeline some part of these liquids in the natural gas itself. Moved principally in the summer months, they could be stripped off and stored in or close to the main natural gas market areas. Subsequently, they could be re-introduced—as is common practice now—for gas enrichment and hence system capacity boosting during periods of peak demand. This they can do because their heat content is higher than that of the natural gas. Also, since they may be stored as liquids, they may provide a convenient way of overcoming what in many instances is a difficult terminal storage problem in respect to the natural gas itself.

Some idea of future production has already been obtained through the link which these liquids have with natural gas. Their market destination is something else again. Canadian needs have been independently assessed as approximating 2% of total domestic energy requirements in 1965 and 3% in 1980. The remainder—at least on balance—is available for export. The following figures reflect, in a very general way, the prospective relationship between Canadian production and Canadian consumption of natural gas liquids:

(quantity in millions of barrels)

	1955	1965	1980
Production	2.5	27.0	80
Canadian requirements	2.5	20.0	60
Difference	—	7.0	20

For geographical reasons, Canada will be both an exporter and an importer of these liquid petroleum gases. However, the division which may eventually develop between Canadian production for home consumption and Canadian production for sale elsewhere is difficult, if not impossible, to forecast at this time. All that can be said with any degree of assurance is

that, at sometime between now and 1980, actual output may be in excess of available markets and resort will, therefore, be had, if only intermittently, to the return of these natural gas liquids to underground storage. During the next few years the development of economic transportation facilities and related storage will be the main problem facing the natural gas liquids industry.

9

THE ELECTRIC POWER INDUSTRY

Section I: Introduction

Canada is exceptionally well endowed with water power resources. Being both large and conveniently located they have played a major role in its economic development. Among other things they have helped to make up for a lack of mineral fuels in central Canada. They have made possible the processing of forest, mineral and other primary products on a scale unmatched anywhere else in the world. And, by making low-cost electrical energy available to the nation's homes, farms, stores, offices and factories, they have contributed in innumerable ways to the exceptionally high standard of living which Canadians now enjoy. (See charts: Average Selling Price of Electricity, and Electric Power Consumption vs. National Income, 1952.)

Thanks to a favourable climate and to the right kind of topography, to widespread precipitation, extensive drainage basins and readily harnessed water power sites, Canada has made tremendous strides in this important energy field. With the exception of the United States, this country has installed more hydro capacity than any other nation in the world.[1] While Norway's per capita installation still tops the list at 1.6 horsepower, Canada is second with 1.1 horsepower,[2] followed in order by Switzerland and Sweden. (See chart: World's Leading Producers of Electricity in 1955.) Present plans which include the harnessing of substantial new powers may also give Canada the lead in this respect a decade or so from now.

The prominence of water power resources in the Canadian economy is reflected in the fact that Canadians, person for person, use six times as much hydro-based electricity as people in the United States. Americans for reasons of location have had to rely much more heavily on thermal sources—coal,

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[1]At the end of 1955, the reported water powers were: U.S., 40 million h.p.; Canada, 18 million h.p.

[2]It is interesting to note that per capita installation in Quebec is presently 1.6 h.p.; B.C., 1.3 h.p.; Ontario, 0.8. h.p.; and in both the Prairies and the Maritimes 0.3 h.p.

AVERAGE SELLING PRICE OF ELECTRICITY

	COUNTRY	YEAR	CENTS PER KWH
1	YUGOSLAVIA	1952	6.0
2	TURKEY	1949	4.9
3	LUXEMBOURG	1952	4.3
4	POLAND	1947	3.6
5	BELGIUM	1952	3.4
6	DENMARK	1951	2.7
7	GERMANY	1952	2.4
8	FRANCE	1952	2.3
9	NETHERLANDS	1948	2.2
10	AUSTRIA	1952	2.2
11	IRELAND	1952	2.2
12	UNITED STATES	1954	1.5
13	UNITED KINGDOM	1952	1.5
14	SWITZERLAND	1952	1.4
15	CANADA	1953	0.8
16	NORWAY	1951	0.4

CANADIAN AVERAGE PRICES

PR. EDWARD IS.	1954	3.88
YUKON NWT	1954	2.18
ALBERTA	1954	1.79
NOVA SCOTIA	1954	1.69
NEWFOUNDLAND	1954	1.68
SASKATCHEWAN	1954	1.59
NEW BRUNSWICK	1954	1.46
BR. COLUMBIA	1954	1.37
ONTARIO	1954	0.80
MANITOBA	1954	0.73
QUEBEC	1954	0.47

WORLD'S LEADING PRODUCERS OF ELECTRICITY IN 1955

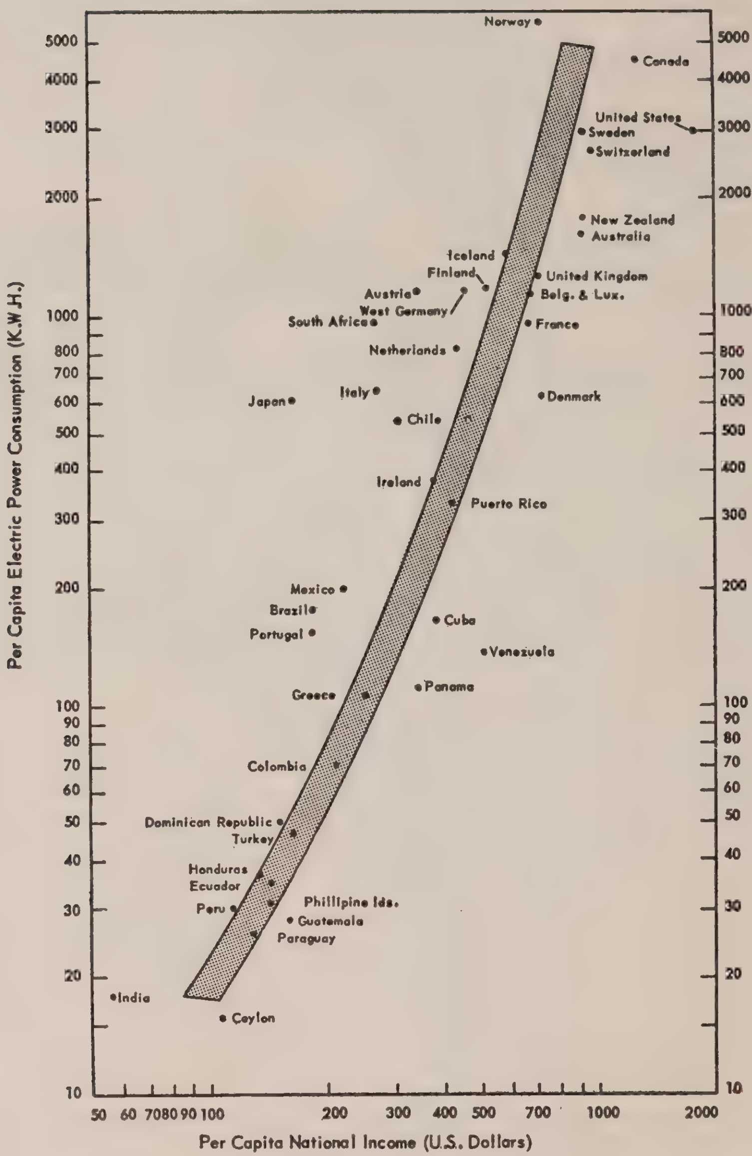
	COUNTRY	POP (000)	KWH (Millions)	KWH PER CAPITA
1	NORWAY	3,425	22,300	6,500
2	CANADA	15,600	81,400	5,200
3	UNITED STATES	165,248	625,000	3,800
4	LUXEMBOURG	308	1,105	3,600
5	SWEDEN	7,260	25,000	2,900
6	SWITZERLAND	4,978	13,100	2,640*
7	NEW ZEALAND	2,136	4,080	1,910*
8	AUSTRALIA	9,200	16,200	1,760
9	FINLAND	4,238	6,800	1,600
10	UNITED KINGDOM	50,968	80,400	1,580*
11	WEST GERMANY	50,000	74,000	1,480
12	BELGIUM	8,850	11,200	1,265
13	AUSTRIA	7,000	8,400	1,200*
14	UN. SO. AFRICA	13,669	16,400	1,200
15	FRANCE	43,300	49,200	1,110
16	NETHERLANDS	10,747	11,200	1,040
17	U.S.S.R.	220,000	175,200	800
18	DENMARK	4,440	3,400	770*
19	ITALY	47,837	36,600	765
20	JAPAN	88,900	63,500	710
21	IRELAND	2,909	1,540	530*
22	SPAIN	28,976	12,300	425
23	CHILE	6,774	2,380	350
24	MEXICO	29,600	7,000	236
25	PORTUGAL	8,765	1,880	215

*EXCLUDES PRODUCTION OF ESTABLISHMENTS PRODUCING FOR THEIR OWN USE.

ESTIMATED CANADIAN PRODUCTION IN 1955

QUEBEC	4,520	36,000	7,960
BR. COLUMBIA	1,206	8,300	6,900
CANADA	15,600	81,400	5,200
ONTARIO	5,183	26,600	5,140
PRAIRIES	2,804	6,500	2,320
ATLANTIC	1,761	4,000	2,170

ELECTRIC POWER CONSUMPTION versus NATIONAL INCOME, 1952
FOR SELECTED COUNTRIES



SOURCE: *REPORT OF JOINT COMMISSION ON ATOMIC ENERGY*
McKINNEY REPORT — WASHINGTON, 1956

oil and natural gas—to meet the expanding needs of the main centres of population and industry.[3] Canadians enjoying an abundance of water power have been encouraged by its relatively low cost to use it more generously. With the sole exception of rural customers, whose costs are affected by other factors like low density of population, it may be said that Canadian customers pay on the average considerably less for their electrical service than corresponding customers in the United States. The ratio varies from less than one-third for industrial users to about one-half for residential and commercial customers.

An abundance of readily installed water power is only one reason for Canada's favourable position. Lower prices also stem from a host of other considerations. Most of the nation's power utilities are already large enough to have achieved well balanced year-round operations. The remainder are mostly on-site power users whose transmission and distribution costs can be held to a minimum. Timing has favoured these Canadian plants for many of them were built when construction costs were only a fraction of what they are today. Canadians have also been able to avoid the inflationary effect of rising fuel costs—something which has been a common experience in thermal power using countries since the late 1930's.

Experience has also been an invaluable asset which, in the related fields of engineering and operations, has been accumulating for nearly 75 years.

Just as soon as suitable equipment was available, Canada began to harness its more accessible hydraulic resources. Early records show, that water power was used for lighting sawmills in Ottawa as early as 1882. This was the same year in which electricity was offered for sale in London and New York. Before 1890 it was being distributed throughout a number of towns in Ontario and Quebec. What was probably the first really long distance transmission line in the British Commonwealth was constructed in southern Quebec in 1895. Along with the perfection of the electric motor and the adaptation of electricity to metal refining and the manufacture of electro-chemicals, the advances in the transportation of power started the ball rolling. Many a new power-using industry and many a major network can trace its early beginnings back to around 1900.

At first, industry tended to concentrate on the production of electric power for its own use, factories and street railways preferring to run their own generating facilities rather than be dependent for their power on specialized utilities. But with the problems associated with large scale generation and transmission largely solved, the economies inherent in load balancing and guaranteed service were bound to make themselves felt. Across the country the first lines of what have subsequently become giant networks were laid. Firsts of the nature of Ontario Hydro were soon to be cited as

[3]Over 90% of all the power produced in Canada is generated hydraulically compared to around 20% in the U.S. and less than 3% in the United Kingdom.

examples of what could be done by other public utilities the world over. Private initiative, meanwhile, was largely responsible for bringing in the large new electro-metallurgical and pulp and paper-making establishments which sprang up across the country before 1914, during World War I and throughout the 1920's. As a result of all this the amount of purchased power grew rapidly and, before the Great Depression got under way, less than 10% of the nation's output of electric power was being produced by other industries for their own use.

Looking back, one can trace the expansion, not only of power production but of the power-using industries by selecting those dates on which output surpassed yet another billion kilowatt-hour mark. Canadian hydro plants first generated more than a billion kilowatt-hours in the month of May, 1926. Consumption passed its second billion in early 1936; its third, in 1941; its fourth, in 1948; and in an astonishing spurt, reached six billion kilowatt-hours a month late in 1953. The tempo of these new demands is still rising. Yet there is little to indicate that this upward trend will change much between now and 1960.

The following table outlining the growth of hydro-electric power generating capacity is also worth noting:

(millions of kilowatts)

	1900	1910	1920	1930	1940	1950	1955
Generating capacity	.15	.75	1.9	4.6	6.5	9.5	13.0

For a long time, electric lighting played the most prominent role in consumption, and 24-hour operations did not become general until after World War I. Then, with new applications for power in industry and great strides in household and commercial uses, better loading patterns began to develop. Residential sales have since presented a record of almost uninterrupted expansion. Sales to commercial and manufacturing establishments, on the other hand, have been modified by changing business conditions. Rarely, however, has power consumption fallen off in any one of these applications. Instead, the tendency for it to replace labour has been accelerated during periods of recession. Productivity has been stimulated, and this, in turn, has speeded the recovery of the more power oriented industries in the Canadian economy.

These longer-run changes have left their mark. Not only has installed power-making capacity[4] risen by an average of a quarter million horsepower a year during the past half-century, but the effectiveness with which this

[4]Capacity for the generation of electric power is measured in horsepower or kilowatts, and the quantity delivered in kilowatt-hours. If generators could be operated continuously at maximum capacity throughout the year, the kilowatt-hours would be 8,760 times the kilowatts. For a number of reasons this cannot be done, principally because the need for electricity is not constant throughout the day, week or year.

capacity has been put to use has risen correspondingly. Whereas in 1950 the generating capacity of utilities was five times as great as in 1920, it was utilized to the extent of producing nine times as many kilowatt-hours.

What has brought about this greater utilization of plant? Year-round, 24-hour operations in chemical and metallurgical type industries have helped to build up base loads. Refrigeration and thermostatically controlled space heating have worked in the same direction. Television is helping to provide an element of continuity, and new seasonal demands like air conditioning are beginning to offset the high winter peak lighting and water heating loads which called for so much standby capacity in the early days.

Along with the development of these mutually compatible and higher priced outlets has come the opportunity, through interconnections with other systems, of making interchange arrangements for the sale of off-peak power. Gone is the day when steam raising was the principal outlet for surplus power. Gone too, is the day when firm year-round power could be bought at bargain basement prices close by the main centres of population and industry. Instead, the small power user has come to enjoy top priority in many utility areas. By being able to pay more, home owners, commercial users and the employers of labour-intensive industries are beginning to command a much larger share of Canada's power production than has heretofore been the case.

Great improvements have also been made from the operational standpoint. Regulation of stream flow through the use of storage has multiplied the power potentialities of many Canadian river systems. Tributary and interbasin connections have made it possible to offset their different generating characteristics. Borrowing or selling during peak demand periods has gone hand in hand with improved methods of long distance transmission. It has been encouraged by the location, close to one another, of systems dependent in the main, on either water or thermal power. It has become a handy cost-cutting device in circumstances where timing or industrial diversity has allowed the load characteristics of one utility to be set off against those of its neighbours. Co-operation, for reasons of economy, has therefore become essential. It has led, almost inevitably, to full blown river basin developments. Exports and imports from adjoining systems (whether they be interregional, interprovincial or international) have also come to be regarded as a must. Often they provide the only way in which standby capacity can be reduced and existing plants can be put to maximum use.

As a result, the capacity factor (or ratio of actual usage to full time capability) has risen considerably. From less than 30% prior to World War I it rose to around 40% in the mid 1920's and on to a high of 65% in 1948. Peak operating conditions are reached only on those rare occasions when daily and seasonal maximum demands coincide, yet even under these circumstances adequate allowance must be made for unforseen outages and

repairs. Utilization of between 60% and 66% of Canada's installed water power capacity therefore represents a technological and administrative achievement in which the nation's electric power producing utilities can justly take pride.

Canada's programme of electrification has had a profound effect upon the mechanization of industry. Fifty years ago factories in this country had only about 1.5 million horsepower in power-driven equipment, and of this less than 5% was powered by electricity. Most of the prime movers at that time were steam engines or water wheels, and industrial establishments were generally a maze of shafts and belts. By the end of World War I, more than half of the nation's power-driven machinery was electrified, thanks largely to the harnessing of a few rivers like the St. Lawrence and the St. Maurice. By 1950, with hydro developments reaching into the hundreds, the figure had reached over 80% and the proportion of the power supplied by the older type prime movers had fallen to approximately one-fifth of what it had been a half century earlier.

The average factory worker in 1900 was aided by some two horsepower of mechanical energy, of which less than one-tenth came from falling water. The 1950 factory worker was much better off. He had the assistance of some six horsepower of which well over five were electrical, and of these five practically all were developed from water power. This increase in mechanization has been largely responsible for the increased productivity of Canadian labour or, put in another way, has multiplied the nation's inanimate labour force considerably. Engineers tell us that Canada's presently installed capacity of over 17 million horsepower if operated at full load is capable of producing energy equivalent to the work of 160 million full-time labourers.

Hydro power and the greater use of electrical machinery have brought other advantages to Canada's manufacturing industries. Choice of location is less restricted in that power can now be delivered economically over a much wider area. Each plant, in other words, is better able to base its choice of sites on such other considerations as proximity to raw materials, other suppliers, labour and other pertinent factors. Electrification has also enabled plant layouts to become more efficient. Space formerly devoted to power plants now is available for other purposes. Breakdowns have been isolated by the extensive use of individual motors. Not only has reliability been increased but electricity, because of its very nature and because of greater opportunities for remote control, has made for surer, cleaner and safer working conditions as well.

In addition, hydro power has been attracting large new power-consumer industries right from the beginning. Abundant supplies of cheap electricity have served to attract firms interested in the refining of aluminum and other non-ferrous metals, in the production of electro-chemicals and in

the manufacture of pulp and paper.[5] These concerns have tended to migrate to areas in which large blocks of cheap electrical energy could be developed alongside either the necessary raw materials or avenues of transportation. Thus electricity was largely responsible for many of the single industry towns which began to spring up across the country, particularly in the 1920's.

Not only has the power industry fostered the rapid growth of large energy-consuming trades, but it has also encouraged the establishment and diversification of the electrical apparatus and electronic equipment manufacturing industry as well. First came the firms which made such heavy machinery as turbines, generators and electric motors. Several of the largest were branches of United States companies. In the late '20's and the '30's plants were also built to make household appliances and radios. The electronics industry gained independent status during World War II, and along with the manufacturer of radar, television equipment and similar types of electrical apparatus and supplies, has since continued to expand both in terms of value of production and quality of output.

From what has already been said, it is apparent that the development of water power has had a tremendous effect upon Canada's economic development. Just how great this effect has been is difficult to measure in over-all terms. Still, it is a fact that for every dollar spent on the construction of new generation, transmission and generation of hydro-electric energy, two dollars have gone into the building and equipping of new manufacturing plants. For every employee engaged by the power companies, 50 have found jobs in secondary industry and for each additional outlay on electric power, as a cost of production, the nation's output of manufactured goods has increased a hundredfold.

No wonder the Canadian industrialist has great hopes for the future. With projects totalling in excess of 10 million horsepower scheduled for completion between now and 1965, he knows that electricity will be available in abundance. He knows, too, from the nature of these projects, that this additional power will be relatively cheap. He knows, as a technologist, that the electro-process and other power-based industries will become more and more important as time goes by. And he knows it is along these lines that Canada, with material resources aplenty, will be best able to compete in the markets of the world.

Whatever happens, Canada's water power industry will continue to grow both in extent and complexity. Accelerating as it does, it will help through its very momentum, to carry along with it the rest of the Canadian economy. Thus, in innumerable and in unforeseen ways it will continue to do what it has done so well before—that is to stimulate industrial development

[5]Two-thirds of all the power used in manufacturing is consumed by Canada's pulp and paper mills and non-ferrous metals smelters and refineries.

in those resource and resource allied fields where Canadians as a people possess their greatest natural advantage.

Section II: the Nature of the Demand for Electricity

Electricity is the most desirable form which energy can take. It is essential in a host of applications. Its price, furthermore, has been falling relative to that of other materials. For these reasons and because further economies of scale will tend to improve its competitive position, the demand for electric power is expected to go on rising at a rate equal to or greater than that experienced over the past 20 to 30 years.

Long range forecasting is by no means new to the electric power industry. Many projections have been made over the years. Yet, with few exceptions, those based on past experience have been on the low side. Demand in other words, has been accelerating. Consumption everywhere in the postwar period has been growing at a rate well above that of the interwar period. Since 1950, particularly in Canada, rates of increase previously unheard of have been attained.

Eventually, the demand for electricity will encounter an upper limit to its course. No one energy supply sector can go on growing indefinitely at a rate greater than fuel and power requirements as a whole. Statistically, in Canada's case, this is 30 or more years away. For our purposes it can therefore be ignored. On the other hand, the development of alternative and cheaper means of generating electric power could (and indeed may) have a moderating influence on Canadian consumption after 1970 or 1975. Were Canada's most suitable hydro sites to have been harnessed and thermal power to have become more economic in the interim, certain international trading industries like aluminum would be tempted to build much of their new capacity elsewhere. Since their demands already loom large in the Canadian power picture, such happenings would tend to flatten out the nation's power consumption curve in the late 1960's and 1970's.

Bound up with this question of advantage is the question of finances. More capital is required in the production, transmission and distribution of electricity than any other form of energy. Because it is more highly processed (and hence a higher form of energy), heavier outlays on construction and machinery and equipment are involved. Demands must be clearly established before the funds necessary to carry out each major development will be forthcoming. In the older and larger utility areas, short-term needs can be projected with confidence. Elsewhere, and particularly in circumstances where new user industries must be established more or less simultaneously, the question of capital accumulation becomes a much more intractable one. In these circumstances access to foreign markets for the products of heavily power dependent industries continues to be of paramount importance.

In this section future demands for electricity will be discussed first in terms of over-all estimates and second in the detail of the principal end uses to which power is put. Finally the main conclusions are discussed and some general observations made.

Over-all projections

Several methods can be used to estimate the over-all demand for electrical energy 10 and 25 years from now. Essentially statistical, they are, if anything, more descriptive of past developments than of future possibilities. By quantifying such past relationships as have occurred between electric power consumption and other measures of Canadian economic activity, they also provide us with an opportunity to gauge what, given certain assumptions as to output, working population, etc., the level of electricity consumption may be in 1980.

Simple projection of past trends

In Canada the long-run upward trend in power requirements from mid-1930's through to 1955 has been in the order of 6% compounded annually. Since 1945 the average rate has been more like 7%. During the last few years additional generating capacity added on an unprecedented scale has made possible several yearly increases in excess of 8%. A recent nationwide survey carried out by the industry points to a better than 8% rate of growth of peak demand between now and 1960.

Looking ahead 25 years we have several possibilities to choose from. Should demand fall back toward the historical long-term rate, consumption, on the average, would grow at between 6% and 7% a year between now and 1980. It would, in other words, double between now and 1965 and redouble by 1975. On the other hand, economic conditions more akin to the past decade might prevail. Were this to be, the consumption of electricity in Canada might rise at better than a 7% rate and requirements in 1980 be more than six times their present (1955) level.

Projection of the demand—G.N.P. relationship

On the assumption that the growth in demand for electricity is related, at least in part, to the expansion of the economy, a multiple correlation analysis was carried out in order to test the closeness of this relationship. A correlation coefficient of .99 was obtained for the analysis, the results of which may be summarized as follows:

(a) year in and year out there is a steady increase in the demand for electricity which appears to be due, not so much to the growth in other sectors of the economy, but to the new and more intensive uses for electricity as such. This results in an annual increase in demand for power in the order of 6%.

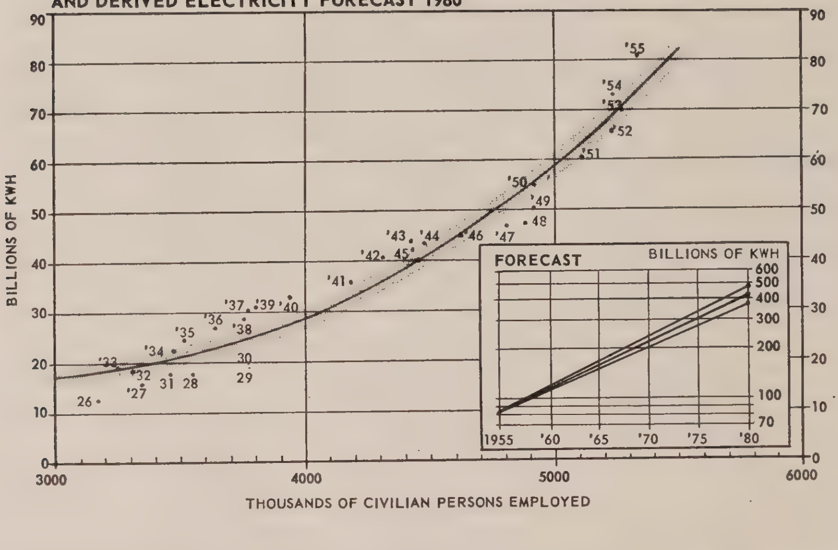
(b) for every 1% volume change in G.N.P. there is a 0.36% change (in the same direction, up or down) in electricity consumption.

In view of the 4.5% rate of increase in G.N.P. projected by the Commission for the next 25 years, our formula implies a corresponding increase in the demand for electricity of approximately 7.5% per annum.[6]

Projection of the electric power—employment relationship

In addition to G.N.P., the level of employment is also a good measure of the size and growth of the economy, and one for which long-term forecasts have been prepared by the Commission. A good correlation was found between electricity consumption and the employed labour force and this has been used to provide the basis for another long-term forecast of the demand for electricity.[7] (See chart: Correlation Between Electricity and Employment 1926-1955 and Derived Electricity forecast 1980.)

CORRELATION BETWEEN ELECTRICITY AND EMPLOYMENT 1926–1955 AND DERIVED ELECTRICITY FORECAST 1980



Corresponding to the Commission's low, median and high population forecasts are employment forecasts of 9.3 million, 9.6 million and 10 million persons for 1980. Our correlation analysis gives derived estimates of electricity consumption equal to 415, 455 and 500 billion k.w.h. respectively.

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[6]This short formula is useful for estimating the year to year rate of increase in power demand. It requires only an estimate of the expected real rate of increase of the economy. For example 1955 over 1954: 6% + .36 (9% real increase in G.N.P.) = 9.2% increase in electricity.

[7]Electricity (billion k.w.h.) = $100.12 - 5.71E + .098E^2$, where E = national employment expressed in hundreds of thousands.

Expressed as annual rates of increase these range from 6.5% to 7.5%; as a multiple of 1955, a five to sixfold multiplication of demand.

Some international comparisons

Canadian experience is not unique. Experts in many countries (at least those most consistently right in this respect) have been forecasting the same or even higher rates of increase for the future.

The past long-term yearly rate for the United States has been in the order of 5.5%. Long practised in these matters, the Edison Electric Institute predicts an annual rate of growth in the order of 6.8% for the United States as far ahead as 1980. Postwar annual rates of increase in Western Europe have varied. For Norway between 1946 and 1953 it was 8%; the United Kingdom 6.7%; Sweden 6.5%; Switzerland 4.6%; and France 6.0%. The latest country-by-country forecasts through to 1975 envisage something like a 6% per annum rate of growth in demand persisting for most of these countries over the next two decades.[8]

The United States Pacific Northwest exhibits many of the same power and industrial structure characteristics to be found in the Canadian economy. There, a 10% annual rate is more descriptive of past experience. Projections through 1965 and beyond contemplate a 7% or 8% yearly rate of increase in demand as being quite possible of achievement.

In the chart, Long-Term Trends in per Capita Consumption of Electric Power, power consumption per capita has been plotted for various groups of countries. For Canada it is shown as rising with minor variations as to rate over the past 35 years. Although per capita consumption in the other countries shown ranged, in 1950, from a low of 125 to a high of 5,000 kilowatt-hours a year, there does not appear to be any great difference in the slope of the trend lines. The annual rates of growth in demand, in other words, do not differ markedly between the economies which are only now beginning and those, like Norway and Canada, which already use it intensively.

With these data in mind one is tempted to conclude that:

(a) in most countries (and regardless of their degree of industrialization) the demand for electricity will continue to rise at a long-run average rate approaching 7% per annum;

(b) that the disparities in per capita consumption may be as great in 1980 as they are today; and that

(c) there is no statistical basis for the contention that, as power consumption increases, the *rate* at which it does so tends to decline.

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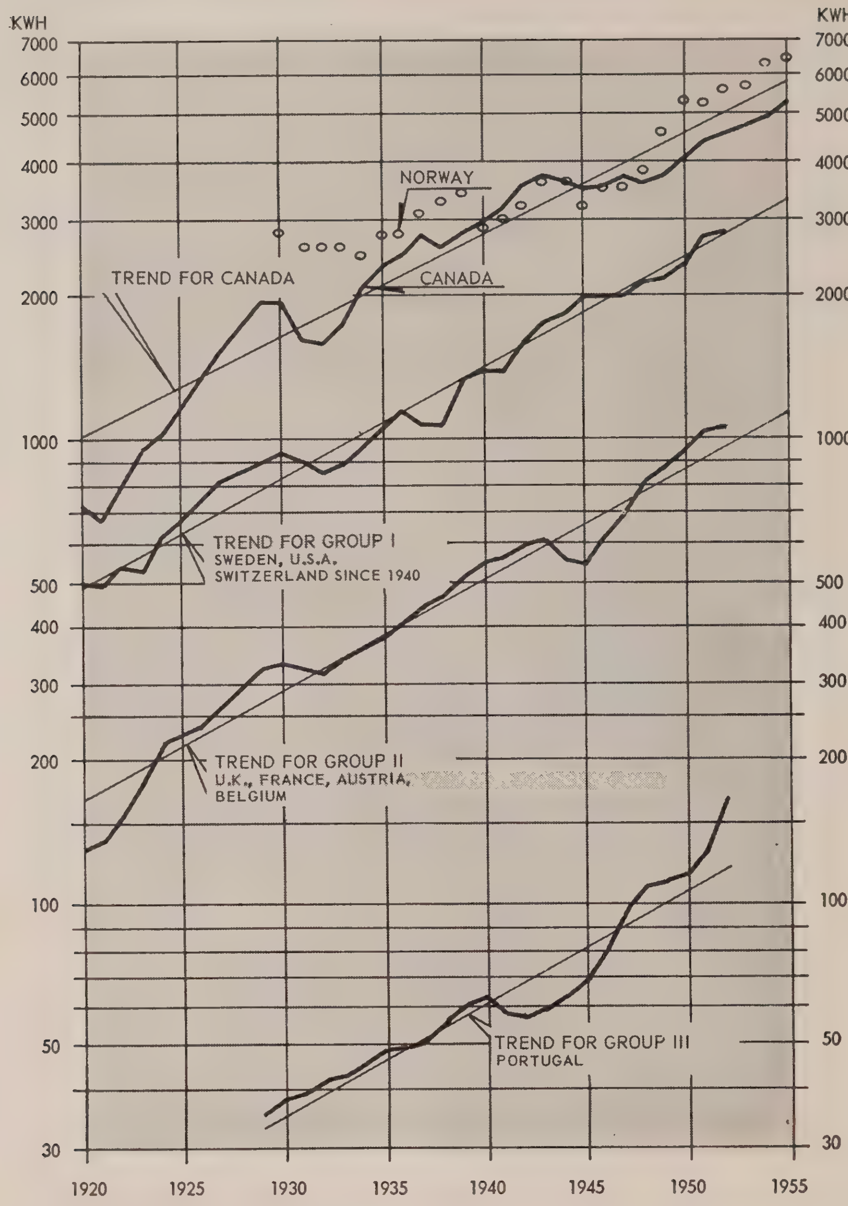
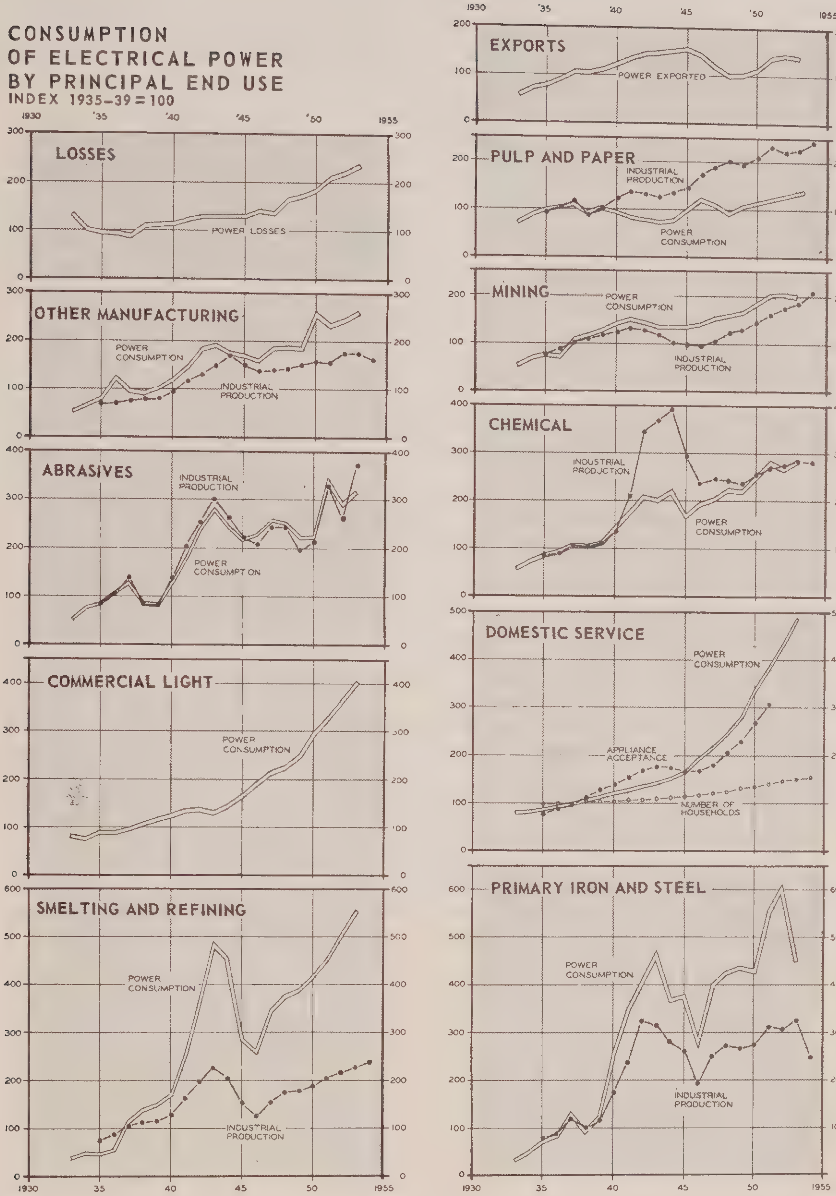
[8]OEEC Report entitled *Europe's Growing Needs of Energy, How Can They Be Met?*, Paris, 1956.

LONG TERM TRENDS IN
PER CAPITA CONSUMPTION
OF ELECTRIC POWER



SOURCE: METHODS EMPLOYED FOR THE DETERMINATION OF ELECTRIC POWER CONSUMPTION FORECASTS —— UNITED NATIONS, GENEVA.


CONSUMPTION
OF ELECTRICAL POWER
BY PRINCIPAL END USE
INDEX 1935–39 = 100
LOSSES
POWER LOSSES
OTHER MANUFACTURING
POWER CONSUMPTION
INDUSTRIAL PRODUCTION
ABRASIVES
INDUSTRIAL PRODUCTION
POWER CONSUMPTION
COMMERCIAL LIGHT
POWER CONSUMPTION
SMELTING AND REFINING
POWER CONSUMPTION
INDUSTRIAL PRODUCTION
EXPORTS
POWER EXPORTED
PULP AND PAPER
INDUSTRIAL PRODUCTION
POWER CONSUMPTION
MINING
POWER CONSUMPTION
INDUSTRIAL PRODUCTION
CHEMICAL
INDUSTRIAL PRODUCTION
POWER CONSUMPTION
DOMESTIC SERVICE
POWER CONSUMPTION
APPLIANCE ACCEPTANCE
NUMBER OF HOUSEHOLDS
PRIMARY IRON AND STEEL
POWER CONSUMPTION
INDUSTRIAL PRODUCTION

Forecast of Demand by Principal End Use

An alternative, though more conservative method of forecasting involves a study of each of the individual components of demand. With this in mind, an examination was made of past relationships between physical measures of output and quantities of electricity consumed industry by industry or end use by end use, since 1935[9]. (See chart: Consumption of Electric Power By Principal End Use.) Using this knowledge and relying on the results of other studies prepared for and by the Commission's staff, it was possible to build up separate projections of each of these component demands to 1980. With this, and making certain assumptions as to exports and line losses, it was also possible to arrive at an over-all estimate of installed capacity in Canada 25 years from now.

Pulp and paper

The record with regard to pulp and paper is exceptional. It is one of the few industries in which power consumption has lagged behind the output of the industry itself. Electricity usage was little different in 1945 than it had been ten years earlier; this despite a sizable increase in industrial output. It was only 50% higher in 1955 though the quantity of pulp and paper produced in that year was more than double the amount manufactured in Canada in the mid-1930's. Only during the last four or five years have the volume of pulp and paper produced and electricity consumed tended to move upward roughly in step one with the other.

Apparently the lag in electricity consumption which began about 20 years ago and persisted until about 1949 was due to the progressive upgrading in the use of electric power. Twenty years ago a great deal of generating capacity was used, essentially, for steam raising purposes. Plants had been overbuilt or demand in other nearby power uses had subsided. Only when electricity began to be in short supply did the fuels begin to monopolize the function of providing heat. Electricity, meanwhile, is being used more as a source of mechanical energy and for activation and control.

Now that most of the "surplus" power has been diverted to more essential purposes, there should be a closer relationship between the industry's volume of output and its electricity requirements. In the past, an average annual increase of 4% in production was accompanied by a 1% to 2% rise in its demand for power. Over the next decade or two, they may be more nearly parallel. For purposes of forecasting a 1% rise in power consumption has been assumed to accompany every 1% increase in the volume of wood pulp produced.

The following table indicates the probable orders of magnitude for 1965 and 1980. Measured in kilowatt-hours, it points to an approximate doubling

[9]Statistics on consumption by major end use were not collected prior to 1933.

in demand over the next quarter century. This rise is less than that anticipated for most other sectors. Thus the nation's pulp and paper mills, now absorbing something like 20% of Canada's electrical output, might drop to less than 10% 25 years from now.

(consumption in billions of kilowatt-hours[a])

	1935	1940	1945	1950	1955	1965	1980
k.w.h.	10.6	10.2	10.9	12.4	15.7	23.0	35.0

[a]All 1955 figures pertaining to consumption have been estimated.

Mining

Mining is the only other major industry in which the demand for power has failed to keep pace with industrial output. Mineral output, as measured in physical terms, has been rising at an annual rate of close to 10%. Power usage, meanwhile, has followed along at about 6% a year; *i.e.* doubling every 12 years.

Several influences have been at work. One has been the decline of underground coal and gold mining. Open-pit operations, characteristic of the newer coal and iron mines, have frequently taken their place. The more extensive use of diesel-driven equipment has also continued to modify the demand for electricity in Canada's mining industry during the postwar period.

Looking ahead, several influences making for a sizable increase in demand are in prospect. Coal and gold mining will become progressively less important in the total. As surface workings become better established they, too, will tend to use electricity for driving their mobile equipment. In the oil and gas fields and in pipelining, electrical motivation will also find increasing favour. Not only does electricity facilitate remote control and cut down direct labour costs, but electrical equipment is much less expensive to maintain. Here, then, we have emerging a new and comparatively large category of demand—one which, because of the future importance of oil and gas, may cause mining to become one of the major demand categories in Alberta and Saskatchewan.

As a result of these influences, requirements in 1980 are expected to be approximately five times their present level. Maintaining its present position relative to over-all requirements, the amount of electricity used by the nation's mines 25 years from now may be in the order of 17 billion kilowatt-hours.

(consumption in billions of kilowatt-hours)

	1935	1940	1945	1950	1955	1965	1980
k.w.h.	1.0	2.0	1.9	2.5	3.5	7.0	17.0

Primary iron and steel

Consumption of electricity by the nation's steel mills differs in two important respects from that of the primary industries already discussed. Not only is power consumption already high per unit of output but power requirements have been mounting even more rapidly than steel production itself. A major cause has been the growth of electric furnace capacity. Besides this, electrification, as in paper making, has also served to reduce labour requirements and at the same time improve control in the driving of rolling mill and other rotating equipment.

Further influences making for a relative growth in electrical demand can be foreseen. The nation's output of steel may rise approximately threefold during the period under review. Electric furnace capacity, meanwhile, may go up by between four and five times. It is also likely that, with the increased use of turbo-open hearths and electric induction heating in the manufacture of steel, other new or as yet unforseen requirements may emerge.

Tentatively, a sixfold growth in consumption by the nation's primary iron and steel mills has been envisaged. The following estimates, while they would still be conservative if electric furnace capacity were to substantially replace present-day open hearths or electric furnace methods used for the reduction of iron ore, indicate the direction in which current developments are pointing:

(consumption in billions of kilowatt-hours)

	1935	1940	1945	1950	1955	1965	1980
k.w.h.	0.3	1.1	1.6	1.9	2.5	5.0	13.0

Other metal smelting and refining

Postwar demand in this category has increased more rapidly than in any other except household use. Since 1945, electricity consumption in non-ferrous metal smelting and refining has risen at an annual rate in the order of 8%; *i.e.* doubling every nine years. Metal output, being weighted increasingly with aluminum, has risen at a more modest rate.

It has been forecast elsewhere in the Commission's studies that the demand for structural materials, and particularly the light metals, will continue with little abatement well into the future. This certainly applies to aluminum, magnesium and titanium. Canadian output in each of these cases has been projected at annual rates in excess of 6%. Other commodities, some of which are only now produced on a small scale, or will be new to Canada, may also receive initial treatment here. This applies to some of the more chemically active metals like sodium, potassium and lithium as well as to the separation on an appreciable scale of uranium-235 from Canadian produced ores. Though chemical leaching processes are becoming increasingly popular, electro-processing will probably remain one of the

principal methods (if not the principal one) for the recovery and purification of non-ferrous metals.

On the assumption that the long-term increase in this category of power demand continues in Canada, we arrive at a metal smelting and refining requirement in 1980 in the order of 95 billion kilowatt-hours. Even larger amounts would be required were the separation of uranium-235 from its naturally occurring and less-fissionable isotope U-238 to become an industry commensurate with aluminum during the next quarter century:

(consumption in billions of kilowatt-hours)

	1935	1940	1945	1950	1955	1965	1980
k.w.h.	1.1	4.0	6.8	9.7	15.0	32.0	95.0

Abrasives

This industry has, so far, been drawn to this country primarily by the availability of low cost hydro-electric power. Its consumption of electricity and its volume of production, furthermore, have moved closely in line one with the other. As for the future, it has been assumed that output will continue to move upward at the same rate as industrial activity generally. Should the abrasives industry actually grow in this way, it would, in 1980, call for approximately three times as much power as it presently consumes.

(consumption in billions of kilowatt-hours)

	1935	1940	1945	1950	1955	1965	1980
k.w.h.	0.3	0.4	0.7	0.7	1.0	1.7	3.0

Chemicals

Since the early 1930's, there has been a considerable variation both in the output of the chemical industry and its requirements for electric power. Ignoring the war and immediate postwar periods both of which were characterized by a high level of munitions production, the ratio between the industry's purchases of electricity and its output of chemicals has been remarkably steady. Projecting this relationship on into the future and assuming a 4.5-fold rise in Canadian chemical production leads to a total demand for electricity from this sector in 1980 in the vicinity of 25 billion k.w.h.

Some further qualification is necessary. As in the past, power consumption will be determined mainly by activity in respect to primary chemical production and, particularly, the manufacture of fertilizers, phosphorous and other electro-chemical products. Technological developments may, at the same time, favour other sources of energy. This is particularly true of the nitrates and their increasing dependence on natural gas as a source material. Having made downward revisions on these grounds, it appears more likely

that chemical industry requirements may be in the order of 20 billion k.w.h. a quarter century from now.

(consumption in billions of kilowatt-hours)

	1935	1940	1945	1950	1955	1965	1980
k.w.h.	1.2	2.0	2.3	3.4	5.0	11.0	20.0

Secondary manufacturing

Though the low cost of electricity has attracted a number of primary industries to Canada, its convenience and efficiency in use have also recommended it to many types of secondary manufacturing. One consequence of this has been a 2% rise in power consumption for every 1% increase in manufacturing output. For example, between 1946 and 1953, the nation's output of secondary manufactures rose at an annual rate of 3.5% while power consumption in this sector increased by about 7% per year.

It is here that automation has yet to make its greatest impact. Because of this and because electricity is generally favoured as a source of motive power and for activation and control, the annual postwar rate of increase in demand of 7% has been forecast as continuing more or less indefinitely into the future.

(consumption in billions of kilowatt-hours)

	1935	1940	1945	1950	1955	1965	1980
k.w.h.	1.9	2.9	4.1	6.2	7.0	13.0	25.0

Domestic demand

Since the end of World War II, the demand for electric power in households has increased more rapidly than in any other consuming sector. Expressed in annual purchases, it has been increasing at a rate of about 13%. Nor is there any concrete indication of slackening in this trend. Even in parts of the country where a high degree of consumer saturation has already been achieved the use of such new appliances as television sets, large refrigeration units and clothes driers is continuing to maintain the momentum of the past eight to ten years.

In 1935, less than 15% of all Canadian households were equipped with electric washing machines, refrigerators and stoves. By 1947, this figure had risen to 27%. The latest survey places it at around 65%. This, along with the more intensive use of electricity in heating water and in driving oil furnace blowers, has resulted in doubling in household sales within the short space of six years.

Though there are only a few remaining areas lacking electric power services, the introduction of additional power-consuming equipment may well serve to maintain the present rate of increase. It has been estimated

that the typical home, if fully electrified, will consume in excess of 20,000 kilowatt-hours of electricity annually. When equipped merely for cooking, water heating, refrigeration and the operation of light appliances, it calls for about 6,000 kilowatt-hours. Presently the Canadian national household average is in the vicinity of 3,000 kilowatt-hours. Manitoba is highest on a per customer basis with 5,000 while the newer residential sections of a number of Ontario and British Columbia towns show an average usage in excess of 6,000 kilowatt-hours per year. In the United States these sales vary widely with a high in the Pacific Northwest of close to 8,000 kilowatt-hours annually.

In preparing the following estimates it has been assumed that per customer usage in Canada will move steadily upward to a high of 10,000 kilowatt-hours per customer in 1980. Were this to take place, domestic service would account for about 20% of the nation's total requirements. Presently it is around 15%.

The appearance of summer peaks, stimulated by air conditioning may also lead to some deterioration in load factor, particularly in the more densely populated areas of the country. Additional peak load hydro, gas turbine and conventional steam thermal plants may therefore have to be installed in order to meet these changing circumstances.

(consumption in billions of kilowatt-hours)

	1935	**1940**	**1945**	**1950**	**1955**	**1965**	**1980**
k.w.h.	1.8	2.4	3.4	6.7	11.5	25.0	75.0

Commercial light and other services

Overall, the trend in consumption in this category has been steadily upward. Maintaining a rate slightly in excess of 5% per annum since 1935, it has obscured short-run movements, upward or downward, in retail and wholesale trade activity. In estimating future requirements, it has been assumed that these demands, in aggregate, will follow somewhat behind rather than parallel domestic usage. An approximate threefold rise in requirements would see commercial uses absorbing something like 10% of total Canadian consumption in 1980.

(consumption in billions of kilowatt-hours)

	1935	**1940**	**1945**	**1950**	**1955**	**1965**	**1980**
k.w.h.	2.9	2.9	5.0	5.2	9.0	18.0	45.0

Exports

Having reached a peak towards the end of World War II, exports have since declined and then risen again. In 1955 they were at an all-time

high of slightly over four billion kilowatt-hours.[10] Relatively speaking, they have lagged well behind the total output of Canadian generating plants.

One reason for this has been the power shortage in Canada (and particularly in Southern Ontario) since 1945. Another has been the recent falling off in export demand, notably in the United States Pacific Northwest. But of even greater significance have been the limits imposed by Canadian legislation. The Exportation of Power and Fluid and Importation of Gas Act, first passed in 1907, requires annual export permits. Longer-term contracts, while they can be negotiated between utilities on either side of the International Boundary are therefore subject to interruption. Because of this, and because administration of the Act has had the effect of limiting exports of Canadian produced electricity to amounts similar to those permitted under previous arrangements, legislation in this country has had its intended effect of minimizing the flow of electricity from Canada to the United States.

Various economic forces are working in the opposite direction. System interchange arrangements have helped to reduce over-all investments in standby and peak-shaving generating facilities. Costs, in this way could also be reduced through interprovincial and international links. Besides, there is the problem of financing exceptionally large power projects; a problem which is particularly acute in circumstances where the growth in local demand does not immediately warrant such an investment. Once in existence such sources of supply might, by lowering costs, stimulate the growth of a much larger Canadian market.

Designed to bring about a progressive repatriation of power (or an eventual balancing of imports and exports) such arrangements could result in a significant short-run increase in export earnings and, at the same time, result in lower cost power to Canadian consumers. Since entering into international sales agreements of this kind presumes a change in federal government policy, no such rationalization of Canada's trade in electricity has been assumed to take place between now and 1980. Instead, exports are shown as remaining at around 5% of total Canadian generation over the next 25 years.

With imports (substantially due to the recovery of water storage benefits) amounting to 10 billion k.w.h. net exports would be about 10 billion k.w.h. or 2.5% of production in 1980.

Losses

In order to arrive at a total figure for consumption, line and other losses must also be taken into account. Showing a moderate downward movement between 1935 and 1947 they have since fluctuated between 9% and

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[10]In 1955 about 5.3% of all the electricity generated in Canada was exported to the United States.

10% of total consumption. Such losses may, if anything, tend to rise rather than fall in future. More electricity will be distributed to urban household, rural, commercial and small industrial consumers. Also more may be lost as a result of the need to transmit power over greater distances to market from coal based generating plants at the pit head or from more remote hydro-electric installations. Ten per cent has therefore been chosen as an approximate measure of total system losses a quarter century from now.

(losses in billions of kilowatt-hours)

	1935	1940	1945	1950	1955	1965	1980
k.w.h.	2.6	3.0	3.5	4.9	7.5	16.0	39.0

Total

In adding up the projected demands for each of these consuming sectors, we arrive at a total power requirement of some 390 billion kilowatt-hours annually in 1980. Growing from approximately 80 billion kilowatt-hours in 1955, demand is seen as multiplying between four and a half and five times over the next 25 years. It is about the same figure as would be achieved by a steady 6.5% annual rate of increase in consumption.

Electric Power Consumption
by Consuming Sectors

(actual 1953; estimated 1965 and 1980)

	1953		1965		1980	
Consuming sector	**Power consumption (MM k.w.h.)**	**%**	**Power consumption (MM k.w.h.)**	**%**	**Power consumption (MM k.w.h.)**	**%**
Pulp and paper	14,715	21.0	23,000	14.4	35,000	9.1
Mining	2,782	4.0	7,000	4.3	17,000	4.4
Primary iron and steel	1,927	2.7	5,000	3.1	13,000	3.4
Smelting and refining	13,087	18.7	32,000	20.1	95,000	24.6
Abrasives	1,030	1.5	1,700	1.1	3,000	0.8
Chemicals	3,970	5.7	11,000	6.9	20,000	5.0
Secondary manufacturing	6,199	8.8	13,000	8.1	25,000	6.5
Domestic demand	9,878	14.1	25,000	15.6	75,000	19.6
Commercial light and other services	7,603	10.9	18,000	11.2	45,000	11.6
Exports	2,424	3.5	8,500	5.3	20,000	5.0
Losses	6,364	9.1	16,000	9.9	39,000	10.0
Total	69,979	100.0	160,200	100.0	387,000	100.0

Some Conclusions and Further Observations

We now have a number of projections to choose from. They range from a low of around 6.5% per annum to a high of over 7%. Results of such aggregative methods as correlations of power consumption with G.N.P.

or the nation's labour force indicate that Canada's total requirements may rise from 80 billion to over 400 billion kilowatt-hours in 1980. Only the foregoing end-use analysis results in lower figures. A 7% has therefore been chosen as the most likely to reflect the upward trend in market requirements in electricity over the next quarter century. (See chart: Electric Power Consumption in Canada 1926-1980.)

Several reasons can be given as to why our more detailed approach yields results which are on the low side. Several of today's major power-using industries may expand at a rate greater than that envisaged in the Commission's other staff studies. The market for pulp and paper may more than double over the next 25 years. Electro-processing could become economically feasible in the case of iron ore. A switch to electricity for space heating in the more prosperous residential districts in some of Canada's larger cities would require more power per residential customer. Also, the export of electricity could lead to the building of more generating capacity than has been envisaged in the foregoing end-use analysis. Finally a 5.5-fold (*i.e.* 7% per annum rate) increase in electricity consumption appears to be more in line with the expectations of responsible officials within the industry itself.

The changing importance of different consuming sectors, one to another, is also worthy of comment. Should the individual end-use forecasts be realized, domestic service and non-ferrous metal smelting refineries will show the greatest gains. Pulp and paper, abrasives, secondary manufacturing and commercial requirements meanwhile will tend to lag behind power consumption generally.

The implications in so far as installed capacity is concerned are interesting. Generally speaking, the uses which tend to depress system load factors are offset by the prospective growth in requirements of the more continuous, power demanding electro-processing industries. Were they to be in exact balance and other influences such as system integration to have little effect, the present national capacity factor (the ratio between total Canadian consumption and power generating capabilities) would remain unchanged at approximately 61%.[11] It is thought that, if anything, the changing nature of the load in Canada, and the more efficient utilization of plant made possible by greater interprovincial and international co-operation, will bring about a further intensification of use. The likely national capacity factor has therefore been put at 62% in 1965 and 64% in 1980.

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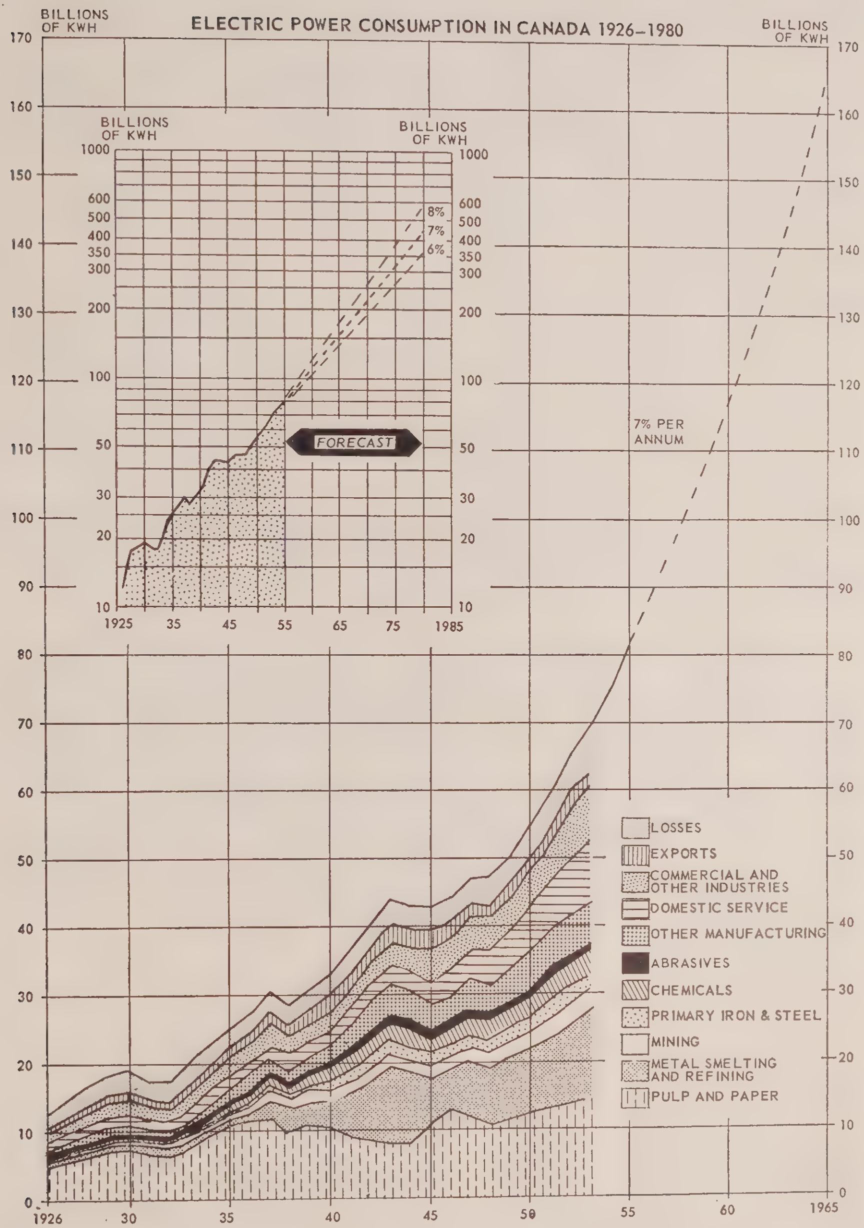
[11]In the United States the national capacity factor has been improving steadily. It rose from 37% in 1939 to 55% in 1955. In Canada the capacity factor of all Central Electric Stations increased from 45% in the mid-1920's to better than 60% at the present time.


ELECTRIC POWER CONSUMPTION IN CANADA 1926–1980
BILLIONS OF KWH
FORECAST
8%
7%
6%
7% PER ANNUM
LOSSES
EXPORTS
COMMERCIAL AND OTHER INDUSTRIES
DOMESTIC SERVICE
OTHER MANUFACTURING
ABRASIVES
CHEMICALS
PRIMARY IRON & STEEL
MINING
METAL SMELTING AND REFINING
PULP AND PAPER

The following table indicates the installed capacity necessary to support a 7% per annum increase in demand in a national power system whose load and other characteristics tend to change in the manner outlined above.

Year	Estimated demand (MMM k.w.h.)	National capacity factor (per cent)	Total required capacity (MM k.w.h.)
1955 (actual)	81	61	15
1965	155	62	28
1980	430	64	76

Section III: Available Sources of Supply of Electricity

Turning more specifically to the question of supply, we find that many of the nation's more favourably located hydro sites have already been developed. Reliance is now having to be placed on others which are either more remote or involve less desirable physical characteristics. Improvements in long distance transmission, the greater use of pump and other water storage, and the interconnection of different river and power distributing systems have had an offsetting influence. Despite this, the delivered cost of hydro power in some of the more highly developed areas of the country is already showing a tendency to rise.

Faced with the alternative of having to go much further afield in search of undeveloped hydro resources, recourse is having to be made, increasingly, to thermal generation. This is the situation particularly in Southern Ontario, Manitoba and Nova Scotia. Unfortunately fuel costs in these areas, being among the highest on the continent, make steam power a much less desirable alternative than it is, say, in Alberta and Saskatchewan where coal and natural gas are plentiful and comparatively cheap. But, before dwelling at some length on the varying prospects for electric power production regionally across the country, let us look somewhat more carefully at Canada's available hydraulic potential.

Canada's Water Power Resources

Unlike the combustion of coal and other fossil fuels for power making purposes, the use of water power does not deplete the resources of a country. Indeed, as long as the sun continues to shine and the rain to fall, the nation's water power potential remains undiminished. It may fluctuate from one season to the next and from year to year, yet the reliable hydraulic energy which can be obtained continuously from any one site can be estimated with a fair degree of accuracy from past data on stream flow, information as to rock formation and other necessary conditions for construction, and from the topography of the upstream area in question.

This has been done systematically over the years by various governmental agencies at both the provincial and federal level. Their findings, as published

annually by the federal department concerned with water resources, are summarized in the following table.

Available and Developed Water Power in Canada at End of Year 1955

(thousands of kilowatts)

Province or territory	Available 24-hour power at 80% efficiency: At ordinary minmum flow	At ordinary six months flow	Installed turbine capacity	Column (4) as a % of column (3)
(1)	*(2)*	*(3)*	*(4)*	*(5)*
Newfoundland	715	2,054	245	12
Prince Edward Island	—	2	1	50
Nova Scotia	19	116	132	113
New Brunswick	92	249	122	49
Quebec	8,128	15,252	5,950	39
Ontario	4,034	5,417	4,004	74
Manitoba	2,486	4,149	594	14
Saskatchewan	410	835	82	10
Alberta	379	938	212	23
British Columbia	5,239	8,204	1,694	21
Yukon and N.W.T.	285	607	25	4
Canada	21,787	37,823	13,061	34

These data, which reflect the position as of January 1, 1956, show that, under minimum flow conditions, Canada's presently measured water power potential is in the vicinity of 22 million kilowatts. The ordinary six months flow data give us a first approximation of the resources available to the industry. Yet even this is not directly comparable to the figures shown in Column (4) relating to installed capacity. It often pays to install additional capacity, some of which may be operative for only a relatively few months in the average year. Because of this practice Canada's measured resources, when fully harnessed, might support a total turbine installation of as much as 50 million kilowatts.[12] Confirmation of this is to be found in the usual practice of the industry of taking the commercially available capacity to be approximately one-third greater than consistent with the conditions of ordinary six months flow.

With a caution customary among engineers, statistics pertaining to some of the lesser known (and yet possibly favourable) sites are frequently disregarded, until such time as the necessary runoff, topographical and dam foundation conditions have actually been subjected to exhaustive survey. In order that these resources be properly quantified, stream flow data must be available over a period of many years. Where a high dam structure is envisaged, or considerable tunnelling is involved, the possibility of using new and improved techniques cannot always be anticipated. Often left out

[12]*i.e.* 30% in excess of ordinary six months flow.

of account until the need arises, are the additional capacities possible through the greater use of storage and stream regulation. River diversions from one watershed to another may also result, sometimes quite unexpectedly, in new freedoms for increased hydro power generation. Thus potentials such as those recently established at Kitimat or envisaged for the Columbia or Fraser river systems had for years been disregarded either as unproven or visionary, if not entirely out of the question.

Therefore, in looking ahead, allowance must necessarily be made for the fact that with more knowledge further water power resources will be added to the nation's potential. Reports down the years relating to Canada's available power producing capacity bear this out. In 1923 the nation's hydro-electric potential at ordinary six months flow was put at 24 million kilowatts. By 1939 this had been revised upward to 25 million kilowatts, and by 1946 to 30 million kilowatts. Now, as the accompanying table shows, it is put at 38 million kilowatts. This still leaves out of account those but partly measured and yet tremendous resources believed to be available on the Hamilton River in Labrador, or creatable by diverting the headwaters of the Yukon, Whiting, Stikine and Unuk Rivers through the Alaskan Panhandle to the Pacific Ocean. Also, no allowance has been made for the repayment in power of down-stream benefits in the United States resulting from the construction of storage reservoirs on the upper reaches of the Columbia and its tributaries in southeastern British Columbia.

Who can tell? Twenty or thirty years from now, with the greater freedoms brought about by the adoption of new construction techniques and further river system integration and electric interconnections, Canada's measured six month ordinary flow potential might be in excess of 50 million kilowatts. The industry then would see this supporting a commercial power potential of between 60 and 70 million kilowatts.

Against this background it would appear that something less than one-quarter of the nation's hydro-electric has, as yet, been put to work. Even when our more optimistic projects of load growth are taken into account, it would appear that Canada would still have a sizable undeveloped water resource available for future expansion in the 1960's and 1970's. Thereafter, and with most if not all of the more accessible sites developed, resort will have to be had to other means of generating electricity.

These forecasts have been made without regard to the cost of developing additional capacity. This cost is bound to increase as more remote sites are developed or more expensive construction is required. The increase may be offset to some extent by improving the efficiency of transmission systems where larger loads permit operation at higher voltage,[13] and perhaps

[13]For long distance transmission or traversing water barriers high voltage direct current shows promise of substantial economies both in terms of reducing power losses and through a reduction in capital costs.

to a lesser extent by the installation of supplementary thermal capacity to look after exceptional peaks in power demands. It is reasonable, however, to assume that the recent upward trend in the generating cost of hydro power near such important consuming centres as Montreal, Toronto and Winnipeg will continue to make itself felt.

This is not to imply that the economic incentive to develop most of the country's more remote power sites will have been removed. Some of them —resembling the Taku project on the Yukon River in British Columbia, and Grand Falls on the Hamilton River in Labrador—will, because of their relative isolation from alternative demands and because of their proximity to waterborne transportation, continue to attract certain of the more power intensive types of primary manufacturing such as the refining of metals, the manufacture of pulp and paper, and the production of electro-chemicals.

Conventional Thermal Plants

In a number of Canada's main industrial centres resort will soon have to be made to sources of electricity other than water power. This has its advantages as well as its disadvantages. Even where the water resources of an area are abundant, the use of fuel-powered generating plants is not necessarily precluded. The optimum operating characteristics of the two often are sufficiently different to complement, rather than directly compete with, one another.

As long as favourable hydro-electric power sites remain to be developed, thermal installations will constitute a complementary source, operating all-out only during periods of high demand or sub-normal river flows. Indeed, in some of the better established hydro power systems, one or more of the coal, oil or gas burning units, used in this fashion, can constitute a most valuable part of the production facilities.

It should not be inferred from this that it is the hydraulic plant which is always called upon to meet the system's base load requirements. In circumstances where many of the more suitable water power resources have already been harnessed, large modern steam stations must necessarily be designed to perform this function. Also, wherever water can easily be stored from one day to the next, the customary Canadian practice is reversed and hydro power can be conserved for the purpose of meeting peak demands. Instances of this practice are not only widespread in eastern United States but also can be found in the Maritimes and western Alberta.

The necessity of having to turn, in places, from hydro to thermal sources of electrical energy is not as distressing a prospect as it was 20 or 30 years ago. Not only do they work well together but the margin of cost between them has been steadily narrowing. Investment per installed kilowatt in the case of hydro power has been going steadily upward due to inflation, the need to develop more remote sites and the added capital expense involved

in long distance transmission. The effects of inflation have to a large extent been offset by improvements in design in steam-electric generation. Also, plants of the latter type can be sited more favourably in relation to system load centres, thereby minimizing carrying charges and power losses inherent in its distribution.

One reason for the growing popularity of thermal generation is the efficiency with which fuel can be burned today as opposed to that of 20 or 30 years ago. Remarkable improvements have been made in the heat rating of conventional steam power plants. The more extensive use, in recent years, of the diesel engine with its exceptionally high thermal efficiency has had much the same effect. These innovations have been such as to effectively cancel out the price rises per ton or per barrel of the fuel which these stations consume. As a consequence of this, fuel outlays per unit of power produced have tended to remain relatively stable. In some areas they have actually declined. One pound of coal today will produce as much electricity as six pounds burned in the average steam station built in 1900. Maximum thermal efficiencies have risen from less than 25% to close on 40% during the last quarter century.[14] Water power, by contrast, with little latitude left for further improvements in over-all efficiency has, therefore, lost some of its competitive advantage over other sources of electricity.

One has but to recount recent Canadian experience to illustrate this point. A large coal-burning base load plant located on the waterfront of Toronto can deliver electrical energy at a cost only about 50% higher than that laid down at Southern Ontario's principal load centres from the new hydro installations at Niagara or built in connection with the St. Lawrence Deep Waterway. Twenty or thirty years ago there would have been a much greater discrepancy between these power quotations. In 1920, for example, it might have cost anywhere from three to five times as much to produce electrical energy by thermal means in Southern Ontario.

So marked have been these changes in efficiency, and so great have been the cost reductions in mining that, where natural gas or strip mined coal are readily available the choice of thermal generation is now more or less taken for granted. Indeed, in southern Saskatchewan and throughout Alberta where fossil fuel energy can usually be obtained for the coal equivalent price of $3 a ton or less, water power, if it is developed at all, is used to supplement rather than to take precedence in meeting the utility system's base load requirements.

There are, in addition to these instances where energy is comparatively cheap and abundant, other areas and applications where hydro-electric power is at a disadvantage. This is so in isolated communities where the

[14]The U.S. average as recently as 1930 was 16%-17%. Now it is in the vicinity of 30%.

demand for electricity is relatively small and subject to considerable variations over time. Also, the uncertain life of new mining areas may make investment in dams and other fixed assets inadvisable. Where this is so, diesel electric generation is frequently the answer. These engines which are better able to meet wider load factor conditions are often employed. Because of these attributes, and because of its high thermal efficiency, the diesel will probably continue to be the workhorse of the industry in the more remote and less thickly populated parts of the country.[15]

More and more is being heard about the gas turbine as a prime mover for the generation of electricity. Within the last few years, it has found application on the Prairies where natural gas is readily available and where the construction of steam plants is handicapped by a lack of cooling water. Now this type of prime mover is also being introduced in British Columbia for firming up hydro power during adverse water years, meeting peak loads and for emergency standby. Flexible in operation, reliable, comparatively inexpensive to build, easy to maintain, and more efficient the colder the weather, these newer types of engines may be used more extensively as time goes by. Yet, because of their heavier demands on fuel as compared with the larger and more elaborate types of steam stations, they are unlikely to be used extensively for the generation of electric power elsewhere in Canada.[16]

Hydro power, then, appears to be labouring under several disadvantages. Usually, it involves heavier capital investment at the outset. Often a great deal of plant and equipment has to be installed rather than building bit by bit in accordance with short-run system demands. Tied in terms of capability to the characteristics of river flow, it must, in a sense, be overbuilt at the outset to look after the exceptional peaks in demand which may be encountered daily or seasonally throughout the year.

Offsetting these are certain important long-run advantages. The rate of obsolescence of water power installations is much lower than that of any type of thermal plant. Operating costs such as those involved for supplying fuel, labour and maintenance, are either non-existent or are small in relation to the total. A steady rise in the level of wages both at the operating and maintenance levels and the impact of continuing inflation in the price of fuel, therefore, favours capital intensive investments of this kind. The burden of their carrying charges, on the other hand, diminishes and, because of the useful life of most water power projects frequently exists well beyond that used for accounting purposes, their real cost in any given system is likely to be less—and sometimes much less—than that associated with other means of producing electricity.

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[15]Diesel electric installations usually are favoured in circumstances where the installed capacity required varies from 200 to 2,000 k.w.

[16]At present gas turbines are being built in a variety of sizes ranging from 2,000 to 25,000 kilowatts of capacity.

It is often with these latter considerations in mind that public utility companies, as well as large concerns whose main activity centres around primary processes, prefer to develop new water power capacity rather than tie their fortunes to the less predictable thermal sources of supply.

In view of this country's great dependence on hydro power a further word quantifying the growing importance of electricity from other sources may not be amiss here. In the ten-year period prior to 1945 growth rate of thermal-electric capacity was lower than that of hydro-electric capacity and, by comparison, quantitatively very small; in the succeeding decade thermal plant capacity increased at more than twice the rate of hydro capacity thereby raising the ratio between the two from one in fifteen to one in seven. Our projection for the next quarter century (*i.e.* from 1955 to 1980) indicates that thermal sources of all types will continue to gain both relatively and absolutely as a source of electrical energy in the Canadian economy.

Growth Trends in Thermal and Hydro Generating Capacity

Time period	Rate of growth Hydro	Rate of growth Thermal	Ratio: thermal to hydro			
1935 to 1945	3%	2%	1945:	1	:	15
1945 to 1955	6%	14%	1955:	1	:	7
1955 to 1980	5%	9%	1980:	1	:	2

Some Reservations re 1980

As in the case of other commodities jurisdictional factors and other industry relationships must also be taken into account. In the foregoing analysis it has been assumed that international obstacles of the type which are presently being encountered on the Columbia River will be overcome; also that a solution to the fisheries problem on the Fraser and other west coast rivers will be found which is consistent with the production of hydro-electric power on a really large scale.

These are important provisos. The projections of consumption described earlier in this report will only be realized if most (if not all) of the larger power sites in British Columbia and the Yukon are harnessed by 1980. Of the nation's remaining and as yet undeveloped water power capacity approximately one-third or between 15 million and 20 million kilowatts is contingent, in one way or another, upon water storage and power export agreements with the United States. Adequate payment for down-stream benefits in terms of electricity must be realized and, in the case of river diversions in Canada, allowance must be made for possible damages suffered by American interests, in the United States Pacific Northwest or in the Alaskan Panhandle. Construction of 15 or more million kilowatts will be held up until such time as the difference between the salmon fishing industry on the one hand and the producers and consumers of power on the other hand are resolved. Certain projects in northern British Columbia

Table 14

LARGE HYDRO POWER CAPABILITIES[a]
(remaining to be developed in Canada as of December 31, 1955)

	Millions of installed kilowatts
On the Island of Newfoundland	0.2
Hamilton River	4.2
New Brunswick	0.5
Quebec	
Lachine	0.9
Beauharnois	0.7
Ottawa	0.9
St-Maurice	0.6
Saguenay	1.0
North Shore, Gulf of St. Lawrence	4.0 (min.)
Rivers flowing into James, Hudson's and Ungava Bays	6.8
Ontario	
International Rapids	0.9
Northeastern Ontario[b]	0.2
Manitoba	
Nelson, Churchill and Saskatchewan	3.9
Alberta	
Peace, Saskatchcewan, Bow, etc.	1.0
British Columbia[c]	
Columbia and tributaries	3.5[d]
Fraser and tributaries	8.7
Nass, Stikine, Liard[e]	6.0
Other coast rivers and possible diversions[f]	4.0 (min.)
Possible downstream benefits (from U.S.)	1.0 (min.)
Yukon—Taku project	5.2
Total (provisional)	54.2

Annual power potential at 70% capacity factor
= 54,200,000 x 8760 x 70/100 = 332 billion k.w.h. (approximately).
Existing stations generated 75 billion k.w.h. in 1955.
In this study the amount of hydro-electricity required to service the expected load in 1980 is 300 billion k.w.h.

[a]100,000 kw, and up.
[b]Excluding the Albany and Severn River systems.
[c]The B.C. government in its brief estimated that the total hydro power resources of that province were in the vicinity of 18 million k.w.
[d]*Problems of Development of International Rivers on the Pacific Watershed of Canada and the United States*, by Gen. A. G. L. McNaughton—paper submitted to the World Power Conference, Vienna, 1956.
[e]A suming no diversion of the Columbia into the Fraser River system. Were this to be done, it would add some 4.5 million kw. to Canadian capacity.
[f]See *Major Undeveloped Water Powers of Northern British Columbia* by A. J. Smith, McElhanney, McRae, Smith and Nash, Vancouver, B.C., February, 1955.

are confronted with the need to resolve difficulties of both these natures simultaneously.

Agreements of mutal benefit may be struck. Co-operation locally, internationally and between industries will help to reduce costs and encourage the greater use of electric power. A prior condition, however, is a set of basic principles—rules which are effective both ways—and agreed upon by all concerned whether they be provincial, state, federal or purely local in character. These will take time to negotiate as will subsequent hearings, project by project, before the various regulatory authorities charged with administering these matters at the various political levels. Here we have

assumed the best of all possible worlds; namely that the intelligent thing to do is bargain and that in bargaining the most beneficial development of Canadian and American resources will be realized.

Section IV: Financing of Future Power Projects

Until quite recently more money was raised and more money invested each year in the generation, transmission and distribution of electric power than in the production, transportation and marketing of coal, oil and natural gas combined. Even today capital outlays for this purpose approximate that spent on all phases of oil and gas development from exploration through transportation and processing to marketing.[17] This situation is unlikely to change substantially in the years ahead. Should the commodity forecasts described in this study be realized, the volume of funds required for the construction and equipment of new electric power stations, transmission grids and retail outlets will continue, as now, to range between 40% and 50% of total investment in the energy sector of the Canadian economy.

(investment in $ millions)

Year	Electric power[a]	Oil and gas	All fuel and power[b]	Electric power as % of all energy industries
1948	232	84	331	70
1955	405	461	908	45
1980 Est.	2,050	2,718	4,800	43

[a]Central electric stations only.
[b]Including fuel wood, coal, coke and manufactured gas.

In view of the lesser amount of energy involved, these proportions may, at first glance, appear to be unduly high. One must bear in mind, however, that electricity, as compared with the fuels, is a highly manufactured product. Being more efficient in use and usually involving a lesser investment on the part of the consumer it is inherently capable of earning a higher price. In meeting the needs of industry and of the community at large, the electric power utilities are, therefore, called upon to invest more money per unit of output than is the rule with coal, oil or natural gas.

The amount of capital required is also affected by the nature of the available resources and by the number, variety and regional concentration of the customers served. Hydro-electric installations are usually much more expensive than thermal stations to build.[18] Also, the capital cost per installed kilowatt of thermal capacity varies according to the nature of

[17]Investment intentions by the central electric station industry alone approximate $600 million for 1956. Total expenditures on all oil and gas were expected to be in the vicinity of $650 million. Were investment outlays by industries producing electricity for their own use to be added, electric power would still be larger than the other two taken together.

[18]Since 1950 the average investment per installed kilowatt of generating capacity in Canada has been : hydro $225; thermal stations $125.

the fuel burned and the type of equipment involved. Ranked in descending order, they are (a) those burning coal (especially the lower grades), (b) plants burning oil or natural gas and (c) gas turbine installations. Further complicating these comparisons are such features as the location of the proposed plant with reference to its load, the complexity of the transmission and distribution problems involved, and, further, the nature of the load to be served. Under certain circumstances these factors may operate in favour of employing water power as the source of electricity, *e.g.* if it is serving one or more nearby primary or heavily powered dependent in a remote area of the country. The choice of thermal installations, on the other hand, is likely to be made more frequently in highly developed areas where one or more of the fossil fuels is available in quantity and at relatively low prices and where the demand for electricity tends to fluctuate more widely due to a preponderance of residential, commercial and small industrial requirements. Obviously the interrelationships and effects of all of these factors varies from one part of the country to the next.

In contrast to oil and natural gas, Canada's electric power resources have, for the most part, been developed and financed by Canadian capital for use in Canada. Also the industry has been built up to serve demands which are primarily local or regional in character. Export contracts, if any, have been incidental. Also, because of the large amounts of capital involved and the need to secure the lowest possible interest rates, the generation, transmission and even distribution of electricity has been more susceptible to public financing than is the case in most other industries. Provincial and municipally backed corporations have raised most of these funds through the sale of bonds or by plowing back revenue received from the sale of power. Ownership and control of the industry, therefore, rest essentially in Canadian hands.[19] The principal exceptions are to be found in such power intensive industries as pulp and paper, mining, electro-chemical processing and aluminum ore to the occasional company-owned plant like the Ford Motor Company's steam electric station in Windsor.

This being the case, the task of establishing new facilities in advance of demand tends to fall directly on the shoulders of the local franchise holding company or commission. Such an undertaking is less difficult in areas of long-established use where considerable plant and equipment already exist and where the long-run upward trend in consumption can be projected with confidence 10 or 20 years ahead. The situation is markedly different in circumstances where past demands have been modest (or non-existent) and

[19]The majority of these utilities are publicly owned—often taking the form of provincial commissions or municipal distributing bodies. However, the largest of the private companies (B.C. Electric Co. Ltd., Shawinigan Water and Power, Calgary Power, East Kootenay, Southern Canada Power, Nova Scotia Light and Power and Newfoundland Light and power) are also owned and controlled in this country. Among the privately owned corporations only Canadian Utilities and Gatineau Power stock is known to be substantially in the hands of non-residents.

where present day assets are worth only a fraction of those required to be put in place over the next decade or two. In situations where the remaining power resources are either far afield (usually hydro) or must be harnessed on a very large scale in order to take full advantage of their ultimate potential, complications also arise. Then the attainment of low unit costs at the outset and optimum performance over the longer run are rarely compatible. Only when large new or temporary export markets capable of absorbing half or more of the output from these resources are available can the necessary funds be raised through the usual commercial channels.

Ontario Hydro is doubly favoured in this respect. A giant among North America's power utilities, it must meet the continuing needs of the most highly industrialized and rapidly growing region in Canada. Not only can it predict its load growth with confidence but its bonds are backed by Canada's wealthiest province, Ontario. Ontario Hydro can, therefore, borrow money at comparatively low rates of interest (generally less than 5%). Being a wholly owned public utility, it also does not pay income tax.[20] Hence capital carrying charges (and therefore power rates) are lower to consumers in Ontario than in most other parts of the continent.

At the other extreme—though also publicly owned—is the New Brunswick Power Commission. In order to draw industry to the region electric power must be generated in amounts and at prices much more favourable than in the past. Such water power resources as are available are expensive to harness and are contingent upon storage developments outside of either provincial or Canadian jurisdiction. Such stopgap measures as the erection of small-to-medium sized generating stations fall short of the ideal because they preclude the attainment of a price for electricity which is really attractive to industry. Yet, lacking immediately contractable demands, a relatively small provincial corporation like the New Brunswick Power Commission has difficulty in raising the funds necessary to finance a series of projects which, though beyond the province's present means, could eventually achieve economies of scale more consistent with a high level of consumption.

In the interior of B.C. the problem is, if anything, more complicated. Potentially the demand for power is there. Yet, unless it be for the manufacture of some such energy intensive product as uranium-235, contracts adequate for the financing of large, single stage developments are unlikely to be forthcoming. This is a major obstacle not only on the Columbia, but also on the Fraser and other rivers flowing into the Pacific. Local residential, commercial and manufacturing needs, though rising, are inadequate for this purpose. Hence, it would appear that export contracts, envisaging a progressive repatriation of Canadian-produced electricity, have merit—at least from a fund raising point of view.

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[20]Any corporation, commission or association, no less than 90% of the capital stock of which is vested in Her Majesty, in the right of Canada or a province or municipality in Canada, is not required to pay income tax under Canadian Federal Law.

That the political and economic impediments to such schemes are numerous cannot be denied. Federal licences for the export of electricity from Canada are granted for a period of only a year at a time. As long as this practice continues it is well nigh impossible to raise capital for investments in the several hundred million dollar category. Then there is the matter of advantage. Rates are usually regulated by public bodies. The price paid for electricity is often related to its cost of production. Americans, understandably enough, will strive through the medium of their respective federal and state authorities to obtain Canadian produced electricity at prices not too far above its cost of generation. Canadians, on the other hand, will be out to obtain all the traffic will bear. Agreement as to basic principles will help. But there will still be room for considerable argument, project by project and varying as to the type of ownership and methods of accounting involved. Divergencies of interest, regionally and nationally, can therefore be expected to hinder, if not postpone indefinitely, desirable settlements of this kind.

A few institutional aspects are worthy of mention. Electric power utilities in the United States—and this applies to private as well as public financing—have usually been able to obtain their funds more cheaply than those in Canada. Government money has been made available at exceptionally low interest rates (i.e., 2% or 2.5% on TVA type projects). Federal assistance has also been extended in other forms. Dams, for example, have been partly written off against irrigation, flood control and navigation. Locally owned utilities have been encouraged to work together as "public utility district commissions" in order to secure income tax free treatment of their bonds. These features have all helped to minimize the price paid for electricity. They help to explain why power is still being sold in the Pacific Northwest for as little as 2 mills per k.w.h. Also, having become established, they will continue to make many types of power projects more readily financible in the United States.[21]

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[21]See Report to Congress *Water Resources and Power*, Vol. II, by the Commission on Organization of the Executive Branch of the Government (Hoover Commission), Washington, June, 1955. Included is a table—A-8, entitled "Federal Power Generation, Sales and Revenue for Fiscal 1953, by Project and by Marketing Agency" which shows that, as a result of low interest and tax rates, public power from the Columbia River system was sold at 2.39 mills per k.w.h. in 1953. The revenue per kilowatt-hour received by the Tennessee Valley Authority was 4.43 mills. The average for all federal agencies in the United States in that year was 3.48 mills per k.w.h.

Table A-16 in the same report, entitled Components of Fixed Cost Percentages—Federal and Private Plants, shows the rate of interest (or return) on federal power plants to be 2.5%, amortization, replacements and distribution to be 1.3%, insurance 0.1% and taxes 0.5%. In 1953 privately owned plants paid a good deal more. Their average rate of return was 5.5%, amortization, etc. 0.6%, insurance 0.1% and taxes 4.5%.

It is also apparent from this that the principal differences between the cost components of United States federal and private power rates is in the provisions for taxes and the cost of money.

It is believed that some of these concessions could apply to the financing by United States corporations of upstream storage and other riverflow benefit ventures in Canada. In some circumstances the Canadian utilities would find it difficult, when it comes to money-costs and taxes, to compete with their opposite numbers in the United States. Backed by legislation aimed at promoting the generation of hydro-electric and other power resources, American companies, both public and private, may therefore be in a better financial position to develop Canadian resources in Canada than the Canadian companies themselves.

Meanwhile, as electricity becomes more transportable, the economic incentive to develop whole river basins will grow. In order to realize their full potential, stream diversions from watershed to watershed must also be considered. Whole drainage systems must be seen, not singly, but in their appropriate relationship one to the other. Physical features, good and bad, must be reconciled with the practical aspects of system operation and the contracting of an immediately foreseeable demand. The advantages of obtaining additional revenue from interprovincial or international exchanges of power must be weighed against the institutional and political difficulties which may later be encountered in its repatriation. Meanwhile, lack of information may well postpone and, in cases of undue haste, even prevent optimum development. A great deal more effort therefore needs to be expended on the gathering of physical data, on operational planning for the maximum development of Canadian river systems, and on establishing an institutional framework more amenable to international co-operation in this field before conditions suitable to financing of many of Canada's remaining water power projects can be taken for granted.

Appendix A

Hydro Power Developments and Possibilities in Other Countries

While a map of the world's water power resources will show that they are fairly widely distributed, they tend to be concentrated in central Africa, central Asia, Europe, the Canadian Shield and the mountainous country of North and South America.

Tropical Africa is well out in the lead. It is there, surveys show, that something approaching half of the world's resources are to be found. Today, the potential of this vast region is estimated to be over three times that which may ultimately be developed in all North America, and seven times that available in Canada—itself a most fortunate country insofar as exploitable water power sites are concerned.

There is, of course, a good explanation for Africa's prominent position. In that vast and relatively unknown continent, much of the interior consists

of elevated tableland and many of the larger rivers like the Niger, Nile, Congo and Zambezi, rise and reach considerable proportions in high plateau country before they drop down over cataracts like Victoria and Stanley to the sea. Sites of this kind and others in lesser known places like Madagascar and Ethiopia still remain virtually untouched, their remoteness from the world's principal and industrial centres and the backward state of people in these areas presenting the principal stumbling-block to their early exploitation.

Next to Africa comes Asia. That continent has resources which are believed to account for around one-quarter of the world total. Many are to be found scattered along rivers flowing northward through Siberia and Eastern Russia to the Arctic Ocean, and others occur on those running down the southern slopes of the Himalayas into India and Pakistan. In China, as well, enormous water power may eventually be harnessed on the rivers and streams rising in and around Tibet and coursing down into the thickly populated plains which characterize much of that country.

In Asia, some progress has been made towards putting those vast hydraulic resources to work. But, although this potential amounts to that of North and South America taken together, very little of this power as yet has been developed. Indeed, industrial Japan and nearby Korea, whose combined resources are relatively small, still account for most of Asia's installed capacity.

The continents of Europe and North and South America are roughly on a par as far as hydro-electric power potential is concerned.

In Europe, the principal hydraulic resources are to be found in the Scandinavian countries and along the rivers and streams descending from the Alps and Northern Appenines into the North Sea and the Mediterranean. Much of this capacity has already been developed, particularly in countries like Norway, Sweden, Switzerland, France and Italy where native coal deposits are lacking, and where the production of electricity by thermal means is relatively expensive. The Iron Curtain countries generally speaking, are a case apart. For there, as with the mineral fuels, the untapped reserves of water power are enormous. Some developments like that on the Dneiper are of long standing, but, despite the developments on the upper Volga, those around Leningrad and those based on the swift mountain streams of Trans-Caucasia, much of European Russia's potential still remains to be harnessed.

South of the Panama Canal, the most promising water power sites are located on the humid eastern slopes of the Andes all the way from Northern Venezuela to Bolivia and Peru, as well as along the east coast of Brazil where many of the larger rivers either drop or can be diverted thousands of feet down into the South Atlantic. So far, advantage has been taken of only a few of these possibilities, and South America's main hydro-electric

power utilities are still to be found close by major cities like Sao Paolo and Rio de Janeiro.[22]

As for North America, Canada's hydraulic potential has already been discussed in considerable detail. While the bulk of America's potential waterpowers are to be found in the Western Cordilleras, the greatest progress in harnessing this energy has been made east of the Mississippi. Indeed, with the exception of the undeveloped resources at Niagara, on the lower St. Lawrence and in the State of Maine, little remains to be done to put runaway water to work in the older and more settled areas of the United States. Power from most of the rivers and streams rising in the Appalachians has already been absorbed in meeting the needs of industry on the Atlantic coast, and with the completion of the much publicized TVA project on the Tennessee River, little is left to be done in so far as taking advantage of the waters flowing westward through the southern states is concerned. Because the eastern reserves have been so largely developed, and because the United States lacks topographic and rainfall conditions comparable to the Canadian Shield, most of that country's future developments will be made within a few hundred miles of the west coast. It is in that general region, watered as it is by the heavy rains and deep winter snows which characterize the western slopes of the Cascades and Sierra Nevada, and lacking adequate supplies of indigenous mineral fuels, that most of the future hydro-electric developments in the United States are likely to take place.

As already indicated, the generation and distribution of hydro power bears little relation to potential capacity. Usually, the production of electricity by hydraulic, as well as thermal means, is symptomatic of an advanced stage of industrialization. It is, therefore, confined mainly to North America, Western Europe and Russia. Even today there are only some 15 countries with more than one million horsepower of installed water power capacity.

The United States is far out in front, accounting for over one-quarter of the total. Canada[23] is next in line with around 10%, followed closely by Japan. Other countries with production of considerable importance in the world's picture include Italy, France, Norway, Sweden and Switzerland.

The following table illustrates the relative importance of the hydro-electric power potential which is known to exist in various countries of the world.

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[22]Incidentally, in making these installations and in operating these plants, Canadian capital and engineering know-how have played an important role.

[23]Canada, with just about 1/3 of the population of the United Kingdom, produces about the same amount of electricity. Over the past 30 years output in the two countries has been pushed ahead more or less in step, one depending mainly on hydraulic sources and the other almost entirely on thermal stations.

Undeveloped Hydro-Electric Power of the World, 1952

(ordinary minimum flow — millions of h.p.)

North America	90.5
United States	36.2
Canada	36.6
Mexico	8.5
Other	9.2
South America	62.0
Brazil	20.0
Chile	7.0
Peru	6.4
Argentina	5.4
Colombia	5.4
Other	17.8
Europe[a]	63.7
U.S.S.R.	14.0
Norway	10.0
France	6.0
Italy	6.0
Other	27.7
Africa	249.8
Belgian Congo } Belgium Mandate }	130.0
French Equatorial Africa	40.0
Nigeria and Br. Mandate in Cameroons	13.0
Madagascar	7.0
French Cameroons	7.0
Angola	5.7
Ethiopia	5.7
Liberia	5.7
Mozambique	5.0
Other	30.7
Asia	155.9
U.S.S.R.	64.0
India	27.0
Chinese Republic	22.0
Japan	12.0
Pakistan	7.0
French Indo-China	6.0
Siam and Malay States	5.7
Burma	5.0
Other	7.2
Oceania	23.4
Borneo, New Guinea and Papua	10.5
New Zealand	5.0
Other	7.9
World total	645.3

[a]Europe—Several nations such as Switzerland are unlisted here only because the table is based on minimum flow. Due to irregularity of flow the six-months figure is higher than in many of those countries shown, and is probably a more significant measure of hydro-electric potential.

SOURCE: U.S. Geological Survey, 1952.

Some further indication of the extent to which the water power resources of these and other countries have been utilized is shown in the following table:

Installed and Undeveloped Capacity of the Chief Hydro-Electric Producing Nations, 1952

(capacity in millions of h.p.)

Country	Installed capacity	Remaining undeveloped[a]	Ratio of installed to total
United States	31.0	36.2	46
Canada	14.3	36.6	28
Japan	10.0	12.0	45
Italy	9.5	6.0	61
France	8.0	6.0	57
Norway	4.7	10.0	32
Sweden	5.3	4.0	57
Switzerland	4.3	3.0	59
Germany	4.0	2.0	67
Austria	2.5	2.6	49
Spain	2.7	3.5	43
U.S.S.R. in Europe	3.2	14.0	19
Korea	1.8	3.0	37
Brazil	2.4	20.0	11

[a]Based on ordinary minimum flow.
SOURCE: U.S. Geological Survey, 1952.

This is the situation at the present time. Yet the electric power industry is also a dynamic one. Over the next few years, the construction of new plants in many parts of the world will change the present ratios considerably. There are, in addition to the extensive programmes which have already been announced in Canada and the United States, others of considerable magnitude, particularly in Eastern Europe and Asia. Soviet Russia, for instance, claims that two new developments on the Volga will soon be numbered as the largest in the world. Others of note are taking shape elsewhere, notably in Brazil, Argentina, and in Mexico on the Rio Grande.

What will the harnessing of these foreign water power resources mean to Canada? In answering this question one must necessarily assume that projects of the type which are still being advanced for the Canadian east and west coasts will prove to be economic in other undeveloped areas of the world as well. In West Africa, aluminum production may provide the necessary stimulus. Despite its vulnerability in time of war, light metal refining based on water power could commence in the East Indies. The processing of Rhodesian copper by electrolytic means may soon be expanded. Other non-ferrous metals may eventually be recovered in similar fashion in

South America. Should satisfactory methods for treating tropical hardwoods be devised, pulp and paper production may also set the stage for more water power projects. In all these cases abundant supplies of low-cost raw materials, together with cheap water transportation, will probably provide the main incentive to development. Such decisions, as and when they are taken, are bound to affect the world's trade in those semi-processed materials which are rightfully regarded as staple commodities in the Canadian economy.

Appendix B

Note on the Importance of Power Costs

The price at which electricity is made available is only one of the conditions influencing the siting of new plants. Electric power must be available yet its cost is rarely the dominant factor affecting such decisions. Adequacy and continuity of supply, in other words, are essential to industrial development; price much less so.

Underlying this is the fact that electricity is a relatively small item of cost in the budgets of many manufacturing concerns. The accompanying statistics illustrate such variations as have been characteristic of recent (1950-54) Canadian experience.

Outlays on Electricity as a Percentage of:

Industry	Expenditures on fuel and power	Purchases of all materials (exc. fuel and power)	Salaries and wages	Net value of production	Gross value of production
Primary manufacturing[a]	41.0	2.9	14.3	4.9	1.8
Secondary manufacturing	27.7	0.8	1.7	0.9	0.4
All manufacturing	34.9	1.5	3.9	1.9	0.8

[a]Including primary food processing.

Furthermore, outlays on electricity have been declining relative to other costs. This has been true not only as to the purchases of all materials, and the payment of salaries and wages, but also as compared to the amount paid for other forms of energy. A summary of statistics by five-year intervals since 1925 shows this to be characteristic of the period from 1930 onward.

Outlays on Electricity as a Percentage of Total Expenditures on Energy

Industry	1925-29	1930-34	1935-39	1940-44	1945-49	1950-54
Primary manufacturing	36	57	54	48	42	41
Secondary manufacturing	33	36	38	31	27	28
All manufacturing	35	47	48	41	35	35

One thing stands out—the remarkably high ratio of electricity to total energy purchases. Though falling, the former still accounts for one-third or more of all the fuel and power bought by Canadian manufacturing concerns.

In view of Canada's extensive low-cost electricity resources, a commodity by commodity measure of energy as an item of cost is informative. The following tabulation, the contents of which have been obtained from various sources, shows that industries producing titanium, aluminum, silicon, and magnesium tend to be more power-oriented; those processing zinc, electro-furnace pig iron, and most electro-chemicals less so. While such possibilities as the separation of U-235 from natural uranium have been

Power Requirements for Selected Electro-Process Industries

Product	Approx. k.w.h. per short ton of prod.
Titanium metal	45,000
Aluminum metal	19,000
95% silicon metal	17,500
Electrolytic magnesium	16,000
35% hydrogen peroxide	16,000
Sodium metal	15,000
Phosphorus (elemental)	12,000
Electrolytic manganese	10,200
Heavy water	10,000
Carborundium (artificial)	9,100
Calcium cyanamide	9,100
Sodium chlorate	5,200
Rayon	5,200
Phosphoric acid	3,900
Electrolytic zinc	3,400
Fused alumina	3,100
Chlorine	3,000
Graphite	3,000
Calcium carbide	3,000
Electro furnace pig iron	2,400-3,000

Ferro-Alloys

Ferro-chrome (70%) 4,000/6,000
Ferro-manganese (80%) 6,000/7,000
Ferro-molybdenum (50%) 6,000/8,000
Ferro-silicon (50%) 4,000/7,000
Ferro-tungsten (70%) 3,000/4,000
Ferro-vanadium 4,000/7,000

left out of account, this listing is also indicative of the type of export activity which may eventually locate in such surplus hydro producing areas as the north shore of the Gulf of St. Lawrence, the interior of British Columbia or northward along Canada's west coast.

Appendix C

Table 14

DELIVERED POWER COSTS BY REGION, CANADA — 1953

(cents per k.w.h.)

		Canada	Nfld.	P.E.I.	N.S.	N.B.	Que.
Domestic service	Million k.w.h.	9,878	72	13	222	136	1,955
	$ Million	168.3	1.8	0.7	6.4	5.5	34.7
	¢ 1 k.w.h.	1.70	2.50	5.38	2.88	4.04	1.77
Commercial light	Million k.w.h.	3,881	23	11	90	65	982
	$ Million	80.7	0.7	0.5	3.3	2.1	18.9
	¢ 1 k.w.h.	2.08	3.04	4.55	3.67	3.23	1.92
Small power	Million k.w.h.	900	11	1	41	39	177
	$ Million	19.9	0.4	0.02	1.1	1.1	3.8
	¢ 1 k.w.h.	2.21	3.64	3.52	2.68	2.82	2.15
Large power	Million k.w.h.	38,328	104	7	540	421	22,883
	$ Million	201.5	1.1	0.2	6.5	3.1	89.9
	¢ 1 k.w.h.	0.48	1.06	2.58	1.20	0.74	0.39
Municipal power	Million k.w.h.	815	1	1	4	4	202
	$ Million	5.9	.004	0.02	0.1	0.1	1.2
	¢ 1 k.w.h.	0.72	0.44	3.17	1.44	2.25	0.59
Street Lighting	Million k.w.h.	380	4	1	9	9	78
	$ Million	8.9	0.1	0.03	0.3	0.3	1.8
	¢ 1 k.w.h.	2.34	2.36	3.99	3.33	3.33	2.31
Commercial	Million k.w.h.	33,801	248	0.4	328	403	25,134
stations-Hydro	$ Million	173.5	3.8	0.03	7.0	2.0	95.3
	¢ 1 k.w.h.	0.51	1.53	8.78	2.13	0.50	0.38
-Fuel	Million k.w.h.	610	—	31	283	14	13
	$ Million	12.5	—	1.2	4.0	0.2	0.5
	¢ 1 k.w.h.	2.05	—	3.87	1.41	1.23	3.85
Municipal stations	Million k.w.h.	27,268	—	—	415	102	8,647
-Hydro	$ Million	211.2	—	—	4.1	1.7	51.9
	¢ 1 k.w.h.	0.73	—	—	0.99	1.67	0.60
-Fuel	Million k.w.h.	1,177	3	8	—	225	0.3
	$ Million	26.5	0.1	0.3	—	6.1	0.02
	¢ 1 k.w.h.	2.25	4.41	3.75	—	2.71	8.00
Cents per kwh. consumed		0.74	1.59	3.94	1.73	1.60	0.45

(continued on next page)

Delivered Power Costs by Region, Canada—1953 (cont'd.)

		Ont.	Man.	Sask.	Alta.	B.C.	Yukon and N.W.T.
Domestic service	Million k.w.h.	5,166	899	227	282	902	4
	$ Million	70.8	11.1	8.0	8.2	20.8	0.2
	¢ 1 k.w.h.	1.37	1.23	3.52	2.91	2.31	6.05
Commercial light	Million k.w.h.	1,803	230	106	167	400	4
	$ Million	28.4	4.3	4.4	6.2	11.6	0.2
	¢ 1 k.w.h.	1.58	1.87	4.15	3.71	2.90	6.21
Small power	Million k.w.h.	327	87	51	90	75	1
	$ Million	6.6	0.9	1.5	2.6	1.9	0.1
	¢ 1 k.w.h.	2.02	1.03	2.94	2.89	2.53	5.51
Large power	Million k.w.h.	10,800	1,576	123	590	1,218	66
	$ Million	72.7	6.4	3.3	6.0	11.4	0.9
	¢ 1 k.w.h.	0.67	0.41	2.68	1.02	0.94	1.36
Municipal power	Million k.w.h.	438	124	11	20	5	5
	$ Million	3.8	0.2	0.1	0.3	0.1	.003
	¢ 1 k.w.h.	0.87	0.15	1.27	1.50	1.19	0.06
Street lighting	Million k.w.h.	181	29	13	18	38	0.2
	$ Million	4.1	0.5	0.5	0.5	0.8	.009
	¢ 1 k.w.h.	2.27	1.72	3.85	2.78	2.11	4.55
Commercial	Million k.w.h.	1,789	1,883	553	797	2,631	35
stations-Hydro	$ Million	7.7	9.5	1.3	10.2	36.4	0.3
	¢ 1 k.w.h.	0.43	0.50	0.24	1.28	1.38	0.86
-Fuel	Million k.w.h.	11	—	95	141	21	1
	$ Million	0.4	—	1.7	4.1	0.3	0.1
	¢ 1 k.w.h.	3.64	—	1.79	2.91	1.43	16.32
Municipal	Million k.w.h.	16,465	869	—	—	720	50
stations-Hydro	$ Million	139.5	5.5	—	—	7.6	0.9
	¢ 1 k.w.h.	0.85	0.63	—	—	1.06	1.80
-Fuel	Million k.w.h.	2	2	526	402	9	—
	$ Million	0.1	0.2	13.0	6.2	0.5	—
	¢ 1 k.w.h.	5.27	6.28	2.47	1.54	5.56	—
Cents per k.w.h. consumed		0.78	0.72	1.51	1.78	1.37	1.69

10

THE PROMISE OF NUCLEAR POWER

Section I: General Considerations

Introduction

Canada is well endowed with resources for the production of electricity. Many of the nation's water power sites, besides being conveniently located, have proved relatively inexpensive to develop. These, together with an abundance of strip mined coal in certain areas and the discovery, more recently, of large reserves of petroleum and natural gas in others, have been responsible for the relatively low cost of electrical energy in this country.

From now on, however, these advantages may be less marked. Large water power developments on or close to tidewater will, no doubt, continue to attract large electro-processing industries to some of the comparatively unknown or less well developed areas of the country. But in so far as Canada's principal centres of population and industry are concerned, power costs are expected to follow an upward trend. This is something which may happen despite significant improvements in long distance transmission and further advances in the design and operating efficiencies of central electric stations burning conventional fuels.

The advent of nuclear energy, therefore, has important implications. The least it will do is to set a ceiling on power costs in the less fortunate areas of the country. Because of its levelling influence, it should also reduce the wide discrepancies in the price of electricity which now exist between one Canadian power consuming region and another.

The principal role is expected to be played by medium to large (100,000 kilowatt and over) base load type nuclear plants. Others ranging all the way down to stations with a rating of several thousand kilowatts may also perform a useful function. However, their contribution, in terms of total energy, will be modest by comparison. Our first concern, therefore, is with the economics of the larger nuclear power generating capabilities.

Power Cost Expectations

Let us, at the outset, confine our attention to costs. Let us review, in summary fashion, the cost expectations of those most closely associated with the development of nuclear energy. Also, by setting these down alongside similar data relating to more conventional means of generating electricity, let us determine when and to what extent atomic energy will be used to supplement our better known resources for the generation of electric power.

What do we already know about these costs and what can be surmised? Since actual experience is lacking, we must see how far the available facts and our reasoning can take us.

Summarily, the case can be stated in this way. Nuclear fission promises to provide us with an entirely new fuel or source of heat. Its main and perhaps its only saving may, therefore, be in the region of what are commonly referred to as fuel costs. Offsetting this—and the real question is, "By how much?"—are the heavy capital charges which are characteristic of far reaching developments of this kind. The first costs of a nuclear power plant must obviously include all of the land, buildings, machinery and equipment needed for converting steam into electricity—factors which are common to conventional steam plants. But, on top of those charges, one must add the expenses associated with the construction of the reactor, its fuel processing plant (possibly at another site) and the inventory of special materials which are also part and parcel of the reactor's operations.

The most attractive feature of nuclear power is, as we have already noted, low fuel costs. Indeed, they may be such as to make the economics of future atomic energy plants resemble more closely those of our existing hydro-electric installations rather than those of steam plants based on coal or petroleum. This is borne out by the accompanying table which illustrates the relative importance of variable and fixed costs in these different types of stations:

(percentage of total generating costs[a])

Cost category	Coal, oil, or gas fired steam station	Hydro-electric station	Nuclear power station
Variable charges[b]	50	15	10 - 30
Fixed charges[c]	50	85	70 - 90
Total	100	100	100

[a]For stations of 100,000 k.w. capacity, operating at 80% plant factor.

[b]Production expenses, including fuel, labour, supervision, maintenance, engineering and miscellaneous supplies.

[c]Annual and period charges including interest, depreciation, insurance, taxes, rentals and dividends.

Under the heading of variable charges, the cost of labour, supervision, maintenance, and miscellaneous supplies for an atomic-electric station are —in the long run—likely to be comparable with those of our existing steam plants. Expenditures on fuel, on the other hand, may vary considerably. They will depend upon price of natural uranium, the degree of burn-up achieved by the reactors, the extent to which the partially spent fuel can be recycled and the efficiency with which thermal can be converted to electrical energy.

Fuel make-up costs are likely to be highest (say 25% or more of the total price of electricity) in the nuclear power station burning natural uranium in a manner which might be classed as a single pass operation with no recycling, these are also total fuel costs. Under such circumstances, experience suggests that up to 1% of the raw fuel would actually be consumed. The remaining material (including a certain amount of U-235 and by-product plutonium) would, for the time being, be rejected, along with the radioactive ashes generated when the fuel was undergoing fission in the reactor.

The raw material costs would be least (say 5% or less) in a breeder reactor, burning what would, in large part, be reworked material and receiving only enough natural uranium (or thorium) to make up for the losses involved in chemical reprocessing. It is the cost of processing in this case which is expected to be the main determinent of economic feasibility.

In actual practice, it may pay to choose a course somewhere between these two extremes. For instance, some fissile material might be recovered and reinserted into the reactor at a cost below that of natural uranium. Recycling will accordingly pay, up to a limit set by the over-all decline of the total fissile content of the circulating material. Thus, in a multi-pass type of operation, the real cost of fuel may be made to approximate the expense involved in reprocessing the fuel elements. Present indications are that this over-all fuel cost will be in the vicinity of one to two mills/k.w.h.

Even though nuclear fission may, one day, eliminate two-thirds or more of the outlays involved in buying coal or oil, capital charges involved in building and equipping future nuclear power plants will still be relatively high. Experience is lacking but already it looks as if the fixed charges relating to nuclear power stations may be comparable with those presently associated with the production of electricity from water power (i.e. \$200 to \$300/k.w. of capacity). There is little likelihood that within the next 10 or 15 years such costs will be reduced to the figures normally associated with the construction and equipment of modern coal, oil, or gas fired thermal stations (i.e. \$120 to \$180/k.w. of capacity).

Substantial savings will, no doubt, be made. The experience gained in building and operating each reactor will permit further economies in design. The use of little known construction materials may be minimized. The

reactor inventory or holdup of expensive fuel, moderating and cooling substances can be cut down. The emergence of nuclear power as an industry in its own right will also demand the services of centrally located chemical plants. These could be used to meet the processing needs of a large number of separate power stations. Such happenings, coincident with a further decline in the unit price of most nuclear materials, will bring about a progressive reduction in the fixed charges associated with this novel source of electrical energy.

The initial capital outlay on plant, equipment and material inventories is one of our criteria. The rate at which they must be amortized is another. Both have to be taken into account when estimating the fixed charges which nuclear power will have to absorb. Because of a lack of experience, the first nuclear power plants will be assumed to have a relatively short life. In this respect, they will be at a disadvantage compared with hydro, which enjoys a background of long life experience with low maintenance rates. Also, until considerable experience has been gained, depreciation rates are likely to compare unfavourably with those employed in the conventional types of steam stations. In our studies, we have assumed that the reactor portions of Canada's nuclear power plants built in the late 1960's and early 1970's will have to be written off in 20 years. Later, as their performance improves this period may be extended to 30 years—that is to say, to an accounting life similar to that of today's coal, oil and natural gas fired stations. Because there will be a tendency to raise plant operating temperatures and pressures (and hence to run a greater risk of shut-downs), it is not thought that a 50-year life expectation, as is common in the case of water power installations, would ever be established.

The necessity to provide for a rapid rate of obsolescence is an initial impediment but it is nothing new. Most revolutionary processes, particularly those of the chemical variety, have been under a similar handicap at the beginning. Yet, because they gave rise to exceptional and sometimes unexpected economies, they were not too long delayed in arriving on the commercial scene.

One thing that will help more than anything else is for these plants to be run at or near capacity. Shutdowns will be expensive due to the preponderance of fixed charges. To be competitive with other sources of energy, our nuclear power plants will have to be developed to a high degree of reliability. Then, having demonstrated this[1] and having attained a level of costs somewhat better than the best alternative source of electricity, they can be devoted to meeting the continuous (as opposed to the fluctuating) demands

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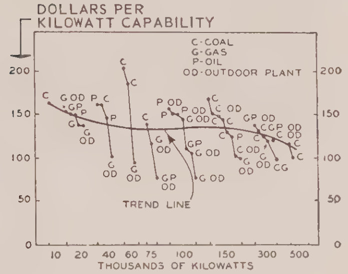
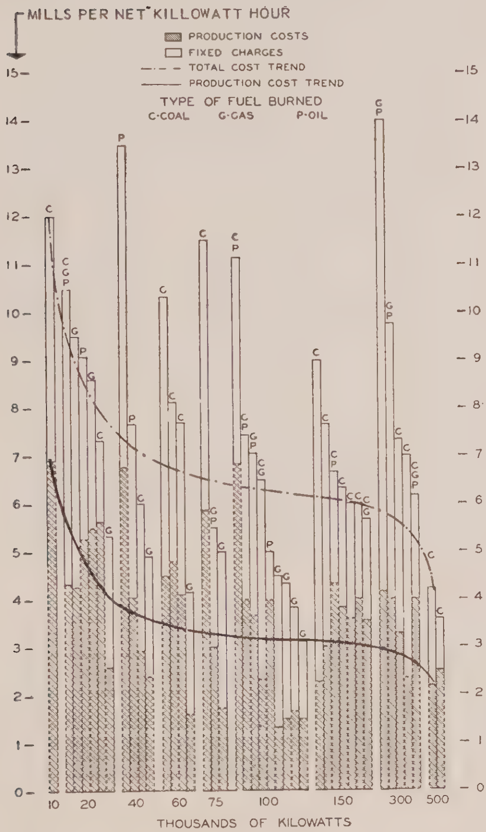
[1]To demonstrate this conclusively one or more nuclear power plants would have to be operated, and operated successfully, for 25 or 30 years. Fortunately, extrapolations based on a decade or so of experience with many types of nuclear power reactors may be accepted as adequate evidence of reliability by some of the larger and more highly diversified power producing utilities.

Present Day
GENERATING COSTS*
in conventional
fuel fired
Electric Power
Stations

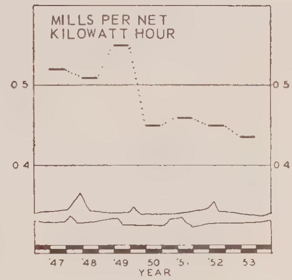
CAPITAL COSTS – 1953
BY SIZE AND TYPE OF STATION



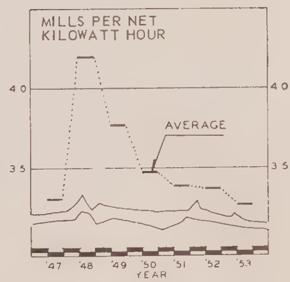
TOTAL POWER COSTS
BY SIZE OF STATION – 1953



MAINTENANCE COSTS
1947 – 1953



FUEL COSTS
1947 – 1953



*IN NORTH AMERICA

ECONOMICS BRANCH, DEPARTMENT OF TRADE AND COMMERCE

of a particular system. The performance of our nuclear power plants, in other words, will have to be judged in relation to that of the other base load capabilities which are also available to the power grid or industry in question.

So far, we have been able to avoid relying on specific cost data. However, forecasts are available which can be used to illustrate the different cost characteristics of conventional thermal, hydro-electric and nuclear base load type stations. (See also chart entitled Present Day Generating Costs in Conventional Fuel-Fired Generating Stations.)

(estimated cost in mills per k.w.h.[a])

	Coal, oil or gas fired station	Hydro-electric station	Nuclear electric station
Production expenses[b]			
Fuel	1.03 - 4.17	0.00 - 0.00	0.50 - 1.50
Station labour	0.11 - 0.48	0.04 - 0.20	0.15 - 0.50
Maintenance	0.10 - 0.30	0.03 - 0.22	0.20 - 0.45
Supervision	0.02 - 0.08	0.01 - 0.10	0.05 - 0.15
Misc. supplies etc.	0.02 - 0.14	0.02 - 0.10	0.10 - 0.30
Total	1.28 - 5.17	0.10 - 0.62	1.00 - 2.90
Fixed charges[c]			
Interest[d]	0.69 - 1.03	0.86 - 2.28	1.14 - 2.86
Depreciation[e]	0.43 - 0.72	0.31 - 0.84	1.00 - 2.50
Taxes, insurance, etc.[f]	0.51 - 0.78	0.12 - 0.32	0.86 - 2.15
Total[g]	1.63 - 2.53	1.29 - 3.44	3.00 - 7.51
Total cost	2.91 - 7.70	1.39 - 4.06	4.00 -10.41

[a]For a hypothetical 200,000 k.w. generating station operating at 80% plant factor.
[b]Production expenses for conventional steam stations and for hydro-electric stations have been estimated from (a) data supplied by Canadian utilities and (b) the detailed accounts and published records of the U.S. Federal Power Commission.
[c]For comparability, public financing has been assumed throughout.
[d]Interest was assumed to be 4% per annum.
[e]Depreciation was calculated on a "straight line" basis using 1.5% for hydro, 2.5% for coal, oil and gas fired stations and 3.5% for atomic electric stations.
[f]In the case of conventional and nuclear fuelled steam plants property taxes are computed at 2% and insurance at 1% of capital cost. For hydro they are respectively 0.5% and 0.12%. An allowance for water rentals has also been made in the latter case.
[g]Total capital costs in the case of the atomic power plant installations were assumed to vary from \$200 to \$500/installed k.w. For coal, etc. fired plants \$120 to \$180/k.w. and for hydro \$150 to \$400/installed k.w.

The preceding table is interesting for a variety of reasons. It shows us that we cannot afford to be arbitrary in our selection of the type of plant best suited to a given base load type service. Obviously, water power is to be preferred, when the capital expenditures associated with the development of a new hydro site can be kept below \$400 per kilowatt of installed

capacity. This ceiling must, however, be revised—and revised downward—as the distance between the proposed hydro generating plant and the system's principal load centre increases.

Transmission charges can be an offsetting factor of no mean significance. An allowance of one mill per kilowatt-hour for every 250 miles of main line transmission can be used as a rough rule of thumb in assessing the locational disadvantages which may be encountered in the case of more remote installations.

Looking ahead, the at-site costs associated with the production of new water powers may be expected to remain relatively stable. Due to the increasing penalty of distance, manufactured construction material and plant equipment costs will be moving upward. This tendency could be counterbalanced by further improvements in the use of earth moving equipment, by fresh advances in tunnelling techniques and by the construction of storage reservoirs at strategic locations to firm up existing capacities. So we come back to the costly matter of transporting power. No doubt, great strides will be made in this direction as well. But it is difficult to believe that the economies of extra high voltage or direct current transmission will be such as to reduce the average delivered price of hydro-electric power.

The economics of a conventional fuel burning steam station usually depend to a much greater extent upon variable expenses—costs which fluctuate more or less in line with level of power production. Where strip mined coal or natural gas are produced locally, outlays on fuel may be held to a minimum. They may be so low, in fact, as to preclude the use of any other source of electricity whatsoever. In other areas, fuel may be much more expensive. Adding in transportation charges, its laid down price may be increased two or three times. It is in instances such as this that the efficiency with which fuel can be burned is of the greatest importance. These may also be the circumstances in which nuclear power will be introduced with greatest advantage.

Forecast figures pertaining to atomic energy are even more in the nature of estimates. They are not at all definitive and are listed merely to indicate a range of possibilities. The upper limit—that of 10 mills per kilowatt-hour—could, perhaps, be attained by large scale nuclear power plants built during the next four or five years using information already available. The much lower figure of four mills per kilowatt-hour is more in the nature of a target. It indicates an objective; a level of costs possible of attainment only after years of development. Whether nuclear power can be driven down below seven mills seems unlikely to be demonstrated before 1965.

We have indicated a probable range of costs. However, nuclear energy will not be competitive anywhere in Canada until its price has fallen below eight mills per kilowatt-hour. At seven mills, it might be able to compete with hydro or coal fired steam power. However, these demands would be

limited. But at six mills, the situation is different. The highly developed power consuming region of Southern Ontario where coal burning stations will soon be the only alternative can already absorb large blocks of power in this general cost range.

The next question to ask ourselves is "When are we likely to get down to costs which are likely to prove interesting to producers in Canada?" Have we any evidence which would lead us to believe that plants capable of such a performance will be under construction within the next decade? Various engineering and economic studies under way in Canada, the United Kingdom and the United States suggest that this is so.

The Time Element

Doubtless, the cost of production will come down. It seems equally clear that each subsequent reduction will be more difficult to attain. With this in mind, those in North America, who have come to take an abundant supply of comparatively low-cost electrical energy for granted, would not be surprised if nuclear energy in a truly competitive sense were first to be generated elsewhere.

Capital costs, it appears, will be the main determinent of economic feasibility. Various estimates relating to different reactor systems have been prepared. Based on preliminary design studies, they indicate outlays for the first generation of nuclear power plants ranging all the way from a low \$200 to a high \$400 per kilowatt of installed capacity.

Such figures must, however, be treated with reserve. Rarely are they all-inclusive. Frequently, no provision has been made for the purchase of expensive fuels and moderating materials. Outlays such as those involved in the purchase of land for exclusion and other purposes are ignored. And, with one or two rare exceptions, no attempt has been made to appraise, even in a very general way, what, for want of a better term, might be classified as the costs associated with research and development. We are therefore forced, for want of more reliable data, to fall back upon Canadian information, the quality and composition of which we know better.

In the case of the 20,000 kilowatt nuclear power demonstration reactor being built near Chalk River, expenditures on plant, equipment and material inventories promise to be in the order of \$1,000 per kilowatt of capacity. Preliminary design studies relating to a 200,000 kilowatt installation indicate that substantial savings may result from the scaling up of heterogeneous rodded-type heavy water moderated reactors in Canada. \$400 per installed kilowatt, even now, appears likely of achievement in or before 1965. By contrast, the present British Calder Hall type stations would cost a good deal more to construct in this country. Employing Canadian wage rates, the per kilowatt cost of such plants when completed in 1963 or 1964 might be

in the order of $600 per kilowatt. Their nearest U.S. counterpart, the Pressurized Water Reactor, might, by then, be built for some $400 per installed electrical kilowatt.[2]

With the second generation of power reactors, it may be possible to shave as much as 20% off the cost of building larger stations. A further reduction of, say, 10% might result from a third round of construction. Following some such sequence as this, we may eventually get down to something in the order of $200 per kilowatt—a level of investment at which electricity produced as a result of nuclear fission might prove to be really interesting.

Each succeeding generation of nuclear power stations might take another five years to conceive, develop, construct and put into operation. (Mr. W. K. Davis, Director of Reactor Development with the United States Atomic Energy Commission, has suggested that a five-year to seven-year interval might be required to complete each new reactor based on the technology demonstrated by the previous one.) Even if their former lifetimes overlap, we may have to wait at least ten, and perhaps 15, years before the economics of nuclear power are clearly demonstrated.

Depending on the method of accounting used—either public or private—$200 per installed kilowatt of capacity is the equivalent, in terms of electrical output, of between two and four mills per kilowatt-hour. In the late 1960's the more conventional types of thermal plant burning coal, oil or natural gas, will still be cheaper to build. On a per kilowatt basis they may still cost anywhere from $110 to $150. Also, since the long-run reliability of our new nuclear power stations may still be open to question, the latter will have to show a decided advantage in some other direction. It is now expected that by 1965, or at the latest 1970, significant economies with regard to fuel consumption, labour and maintenance will have turned out to be sufficient to swing the balance in favour of nuclear power.

Under the heading of fuel substantial savings may be made. Good reasons can be given for expecting that outlays on this account will amount to less than three mills per kilowatt-hour. One mill, in fact, appears to be possible within the next decade. Assuming a modest decline in raw fuel and fuel element fabricating costs and an extension of reactor exposures to the equiv-

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[2]For a detailed cost comparison between the first large-scale British and American nuclear power stations, see "Comparison of Calder Hall & PWR Reactor Types": Report prepared for Division of Reactor Development, U.S. Atomic Energy Commission, by American Radiator and Standard Sanitary Corporation, Redwood City, California, March 1, 1957. According to this study, the Calder Hall reactor, if built in the U.K. and financed by the publicly owned U.K. Atomic Energy Commission, could produce electricity for a total cost of eight mills per k.w.h. The same installation built by North American labour and privately financed would produce electricity for approximately 18 mills per k.w.h. on this continent. The corresponding figures in the U.K. and in the U.S. for the U.S. designed Pressurized Water Reactor were given as 13 and 20 mills per k.w.h. respectively.

alent of as much as 10,000 megawatt-days per ton of fission products, such figures may be achieved by what industry now commonly refers to as a one pass type of operation.

In support of these conclusions, it is necessay to elaborate somewhat. Fuel costs, in a once-through reactor, depend on three factors: the extent to which the fuel can be exposed in the reactor; unit costs of the fuel elements entering the reactor; and the over-all thermal efficiency of the cycle in question. They have been named in this order for a reason. They indicate their order of merit in terms of affecting cost reductions for the future. Exposure time in the reactor, since it may be extended four- or five fold, is bound, in the long run, to be more effective than a halving in the price per pound of uranium fuel rods or an increase of as much as one-third in turbine efficiency. In other words, it is the first of the three—namely exposure time—which offers the greatest opportunity for savings. The price of manufactured uranium fuel is a poor second and thermal efficiency is third.

Engineers confronted with the problem of designing and building a nuclear power plant which could operate reliably in, say, 1961 cannot assume average exposure times in excess of 3,000 megawatt-days per ton. They might use $30 a pound as the price of natural uranium in its fully fabricated rod form; $25 would be a minimum. To be safe, and at the same time avoid serious metallurgical problems, they would also be inclined to keep their operating temperatures and pressures down. This could mean an over-all thermal efficiency of less than 25%. Under these circumstances, fuel costs would work out at about four mills per kilowatt-hour.

Were the engineers asked to deliver a reliable nuclear power plant after 1965, the picture would be much improved. Average exposure times could, perhaps, be raised to 5,000 megawatt-days per ton; the price of fully fabricated fuel elements might have fallen to $20 a pound and, with a modest increase in operating temperatures and pressures, several percent in efficiency might be gained. Once these conditions have been achieved fuel costs could be down to two mills per kilowatt-hour.

Looking on towards 1970, further improvements appear to be in prospect. Most nuclear scientists are now talking of exposures in the order of 10,000 megawatt-days per ton of fission products. Even at 8,000 megawatt-days and leaving out of account any futher decline in element manufacturing costs or improvements in thermal efficiency, fuel costs could be down to one mill per kilowatt-hour. This, we should remind ourselves, may be the situation when natural uranium fuel elements, having been used once, would simply be set aside for others to process as and when the technology of a later day permits.

The economics of regenerative systems, meanwhile, will depend much more on advances which still remain to be made in the direction of chemical processing. A good deal of research and development work on a pilot

plant scale still has to be done before the problems associated with the segregation and recycling of nuclear fuels can be overcome. Uniform practices will have to be instituted. Also, a number of power stations of similar type and design will have to be in operation before economies of scale will be sufficient to ensure efficient processing rates. Then, and only then, is it likely that the over-all fuel costs inherent in the regenerative type systems will begin to approach the minimum figure, of one mill per kilowatt-hour mentioned previously.

Finally, there is the related matter of "other" production expenses. These include outlays for station labour, maintenance, supervision and the purchase of miscellaneous supplies. It can be argued, using recent experience in conventional thermal plants as a guide, that these costs, even when taken altogether, are unlikely to exceed two mills per kilowatt-hour. With a few years of experience they may even be cut in half—that is, in the larger stations, down to around one mill per kilowatt-hour.

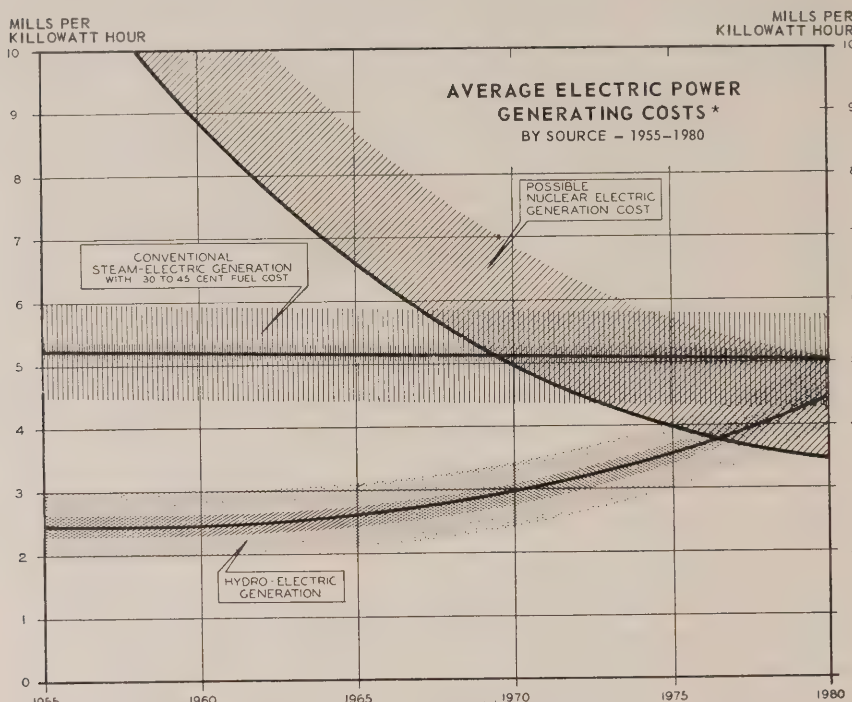
Totalling up these expenses—fixed and variable—one arrives at a figure of between five and seven mills per kilowatt-hour; close, in other words, to the threshold which was mentioned previously as being relevant to the prospective power supply-demand situation in Canada in the late 1960's or early 1970's. (See also chart entitled Average Electric Power Generating Costs by Source, 1955-1980.)

So far, in this report, no mention has been made of the economic feasibility of small or medium sized power reactors. Do they not offer interesting possibilities in areas where the price of electrical energy is several times that of the larger power stations which we have been discussing so far? In many places the cost of power from internal combustion engines (in the 3,000 to 5,000 kilowatt range) is upward of 15 mills per kilowatt-hour. In northern Canada, where the transportation of diesel oil accounts for an even larger proportion of total outlays, charges as high as 30 mills are being encountered.

In order to compete in this price range, small nuclear stations must be manufactured for $600 per kilowatt or less. Figures in this order of magnitude imply quantity production, and mass production is necessarily predicated upon a large volume of sales.

Here, unfortunately, is where we begin to run into difficulties. The characteristics of the market for power have a great deal to do with its price. In order for our small nuclear power plants to show a competitive advantage over alternative sources, they must operate, all-out, for much of the time. Only these outlying communities built around extractive industries can provide this sort of load factor. Some of our mining areas may qualify. Yet, in their case, the need for low cost standby capacity and the problem associated with supplying specially trained personnel, will also have to be dealt with.

Time alone will tell whether the number of units required for this type of service will be sufficient for our engine manufacturers to get their per kilowatt cost down to the $600 level. Most production men think it would take them at least ten years to reach this objective.



* ASSUMING PUBLIC FINANCING AND CAPITAL AT 4 PER CENT PER ANNUM

Fewer disabilities cloud the prospects for reactors in the intermediate (i.e. 10,000 to 30,000 kilowatt) range. Though they may encounter many of the same difficulties as are experienced in the development of really large power installations, there is another and less exacting field of endeavour—the production of process steam. By lowering temperature and pressure requirements and possibly dispensing with our power generating equipment altogether, reactor designs in this size range may be simplified to the point where their cost of producing heat may be competitive with that of boilers fired with coal or oil.

In Canada, at least, such medium sized systems have possibilities. Their heat output would be about in line with the requirements of many of the nation's pulp and paper mills. Meanwhile, their fixed, fuelling and other variable costs, taken together, may eventually be less than that based on imported coal when the latter has to be laid down in some of the more remote forest areas of the country. Other economies may also be found in their favour. Future mill locations, for example, could be chosen with greater

regard to the distribution of timber resources and water transportation and with less concern about the availability of suitable hydro power sites than has been our experience in the past.

Nor are our Canadian conditions unique. Similar opportunities present themselves in Scandinavia and elsewhere. Ten or 15 years from now a goodly number of these comparatively low temperature, medium sized plants may, therefore, be required. Using heavy water as a moderator, single pass systems fuelled with natural metal could be used. Our metallurgical and chemical processing problems can also be kept to a minimum. All these are reasons why reactors of the type with which we are most familiar in Canada, and designed with a view to manufacturing process steam rather than electricity, may be among the first to be truly competitive with other sources of energy on this continent.

Forecast of the Role of Nuclear Power

The part played by nuclear energy in Canada depends, essentially, upon how long it takes the industry to progress downward from one cost level to the next. We already have some indications as to where we may be in the late 1960's. Our progress from there on is even more a matter of conjecture. The first power reactor systems, while they may be the more reliable at the outset, do not necessarily offer the best long-term prospects for a reduction in power costs. Other and more complicated systems, each taking much longer to develop than the last, may ultimately win out in this respect.

This being so, it is generally held that we can look forward to three time phases in the transition to nuclear power. During the first, or induction phase, several large plants may be built, primarily for testing purposes. Government assistance will be required in the form of expenditures on research and development. The power industry and private equipment manufacturers, meanwhile, will be called upon to meet most of the capital and operating charges.

During the second, or intermediate phase, the degree of confidence in the long-term advantages inherent in nuclear power will reach a point where private industry will be prepared to shoulder most if not all of the costs incurred by a programme of this kind. Then an increasing number of the new thermal plants under construction in Canada will be of the nuclear variety. This, according to our calculations, should begin to happen between 1965 and 1975. Thereafter, we will be entering the third phase. Characterized by a high ratio of new nuclear to other thermal plant construction in the order of one to one, it would mark the beginning of an entirely new era—that of the emergence of atomic power as a major (if not *the* major) source of electricity in Canada.

With many qualifications it has been concluded in Section II of this chapter that the long-term rate of growth in consumption of electrical

energy will decline. Perhaps it will fall from the current mid-term rate of 8% to as little as 6% in the late 1970's. Total power requirements, of course, will continue to mount. Annual installations in excess of two million kilowatts may therefore be required a quarter century from now.

The query to which we can now usefully address ourselves is one of supply. Our regional cost studies indicate that hydro-electric power will remain the nation's principal source of electrical energy. Even in 1980, it may add up to as much as two-thirds of the installed capacity in this country. Meanwhile, thermal generation will have become much more important. It will rise from what were negligible proportions a few years ago to at least 30% of Canada's total installed capacity 25 years from now. (See also chart entitled Production of Electricity by Source, Canada 1926-1980.) Listed in terms of millions of kilowatts and broken down by types, it might be expected to run somewhat as follows:

(installed capacity in millions of kilowatts)

Year	Total	Water power	Conventional thermal	Nuclear stations
1955	15.1	13.1	2.0	0
1965	28	22	5.8	0.2
1980	76	49	21	6

Behind these figures are of course two series of volume and capacity factor assumptions. Because of the high loading[3] of nuclear installations statistics showing quantities of electricity produced by major source reveal its expected contribution in an even better light.

Quantity of Electricity Produced By Source

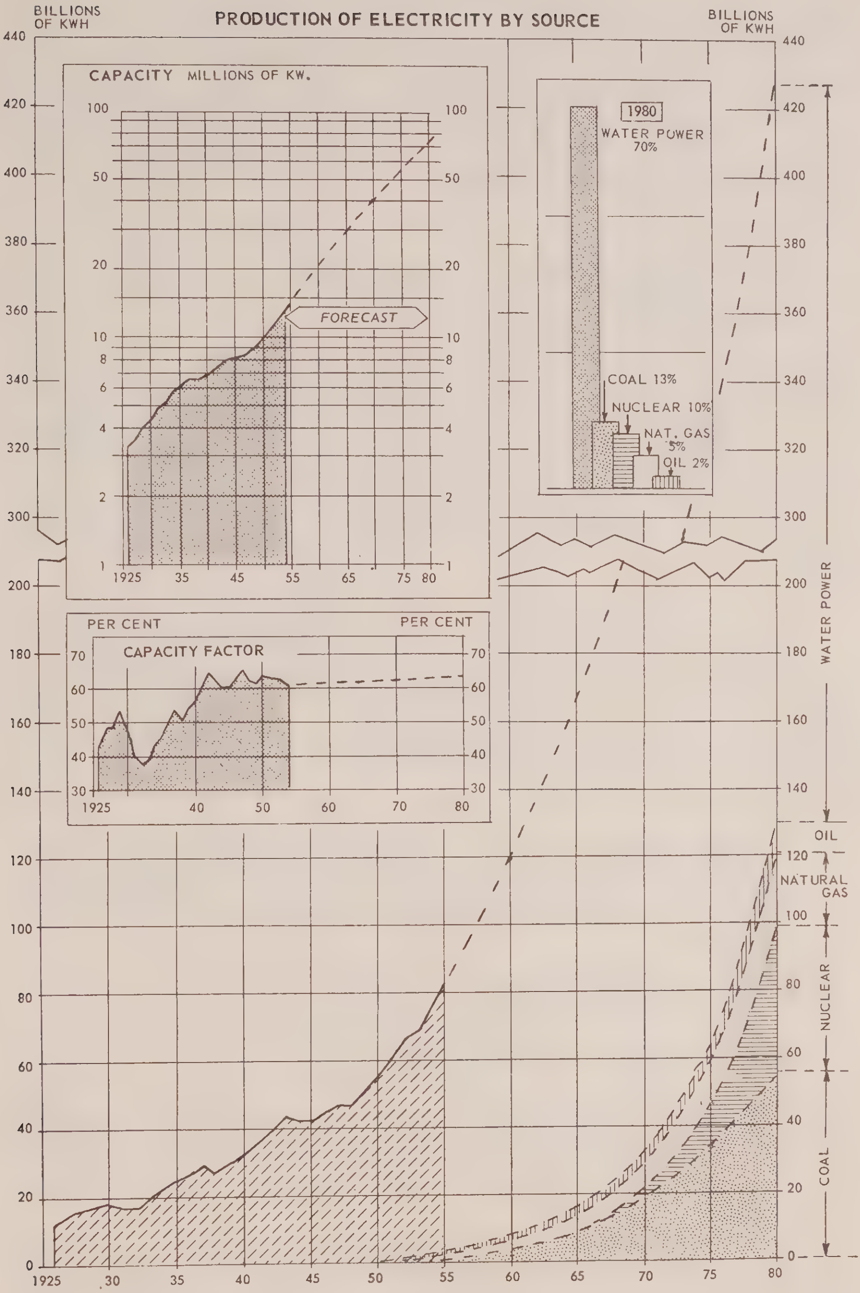
(volume in billions of kilowatt-hours)

Source	1955[a]		1965		1980	
	Volume	%	Volume	%	Volume	%
Water power	77	96	132	85	301	70
Conventional thermal	3	4	22	14.5	86	20
Nuclear stations	0	0	1	0.5	43	10
Total	80	100	155	100	430	100

[a]Preliminary

Thus, the part played by nuclear energy, while modest in the years immediately ahead, may be considerable 25 years from now. Ten percent of all the electricity produced in Canada could well come from this source. Were it to become genuinely competitive several years earlier than envisaged in

[3]The assumed national capacity factors employed in these calculations were: hydro, 67%; conventional thermal, 45% and nuclear stations, 80%.


PRODUCTION OF ELECTRICITY BY SOURCE
BILLIONS OF KWH
CAPACITY MILLIONS OF KW.
FORECAST
1980
WATER POWER 70%
COAL 13%
NUCLEAR 10%
NAT. GAS 5%
OIL 2%
PER CENT
CAPACITY FACTOR
WATER POWER
OIL
NATURAL GAS
NUCLEAR
COAL
1925 30 35 40 45 50 55 60 65 70 75 80

these calculations, nuclear stations could be supplying as much as 20% of all Canadian electric power production in 1980. Unforeseen developments enabling the capital cost of these plants to be reduced to, say, $150 per kilowatt would have even wider ramifications. By enabling nuclear stations to perform a peak as well as base load function, they could further reduce the need to conserve Canada's water power resources or for utilities in this country to burn coal, oil or natural gas.

Section II: Regional Possibilities and Prospects (with Particular Reference to Nuclear Energy)

Regionally there will be variations of course. In a number of areas nuclear power is unlikely to be economic for a long time to come. Either hydro or conventional steam power will remain relatively cheap or the market, itself, will be inadequate to support a sequence of plants each built on appropriate scale. Only where large integrated systems already exist, generating costs are rising or demand is such as to require large year-by-year additions to capacity, are nuclear power stations likely to be installed in any numbers.

In order to assess this need it is necessary to make a number of estimates and assumptions. The demand for electricity must be forecast, utility area by utility area across the country. The amount and delivered cost of available hydro and alternative steam power must be evaluated. Lastly, a reasonable target for nuclear stations must be chosen. In what follows our assumptions have been to the effect that:

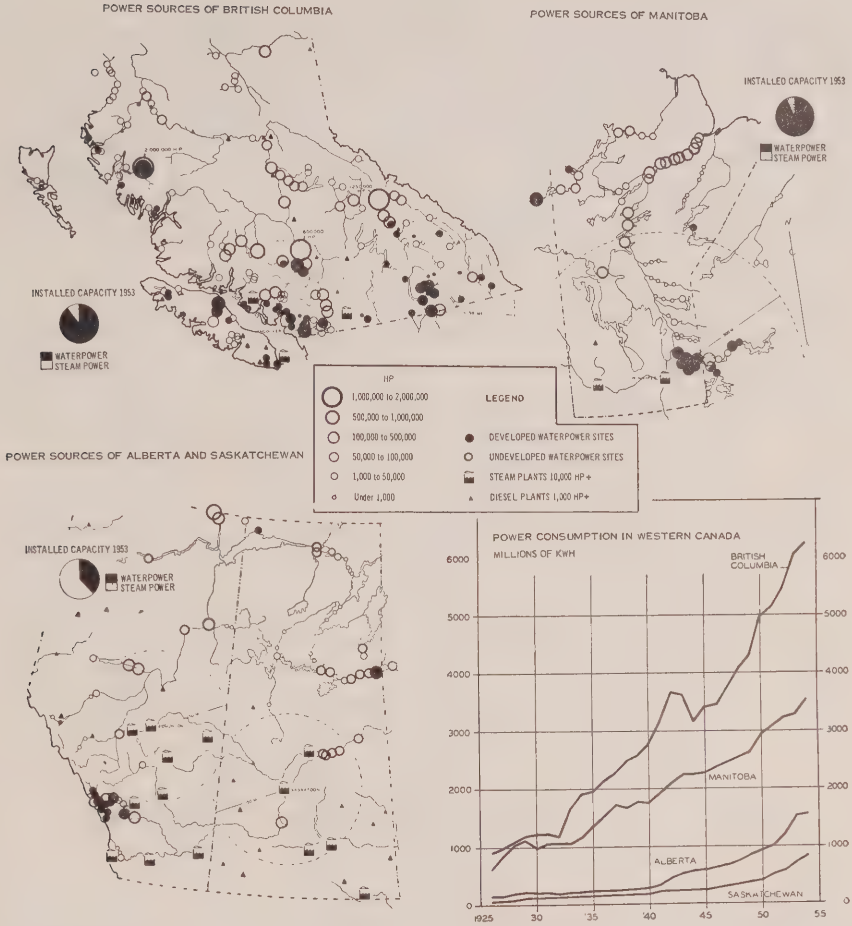
(a) base load type nuclear power plants of 100,000 kilowatt capacity will be capable of producing electrical energy at an average price of around six mills per kilowatt-hour when operated 80% or more of the time;

(b) medium size 10,000 to 30,000 kilowatt capacity plants will be able to generate electricity or equivalent amounts of process steam at a cost in the vicinity of 10 mills per k.w.h.; and

(c) relatively small 2,000 to 3,000 kilowatt plants capable of producing electrical energy at around 20 mills per k.w.h. will have been developed to the stage where they can be manufactured in appreciable numbers.

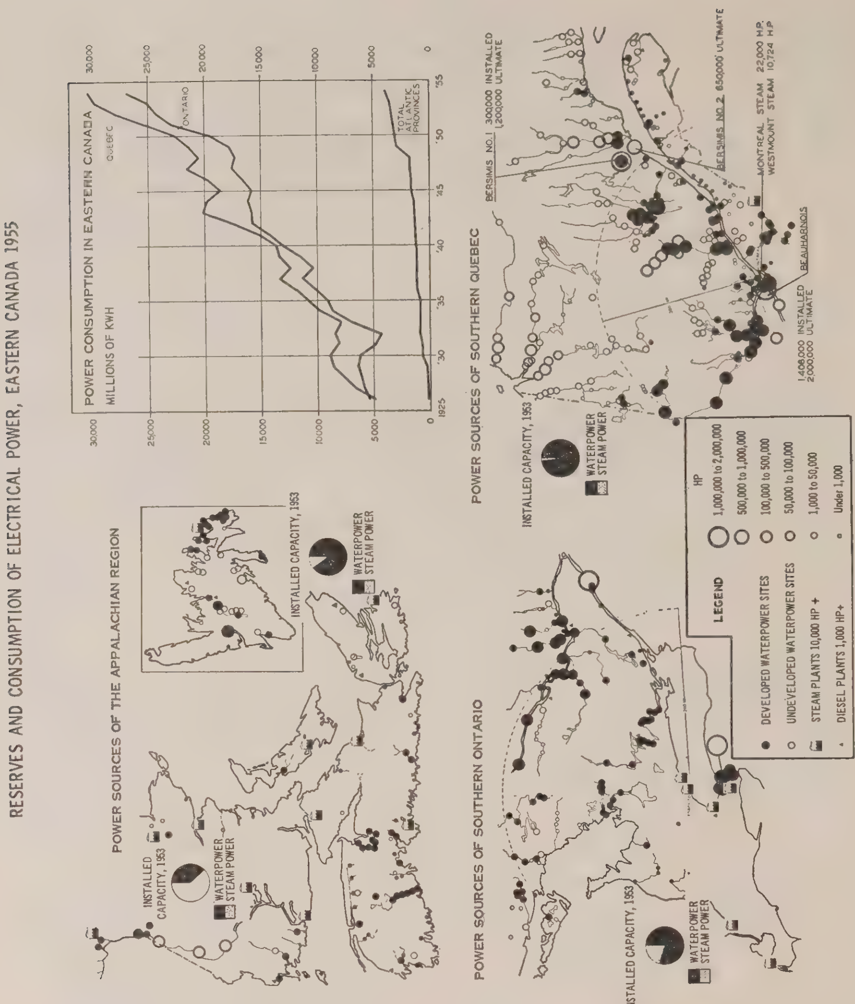
Within this market information and having regard to the optimum size and cost of future nuclear power plants, we are now in a position to analyze more closely the relevance of nuclear power regionally across Canada. (See charts: Reserves and Consumption of Electric Power—Eastern Canada, 1955—Western Canada, 1955.)

RESERVES AND CONSUMPTION OF ELECTRICAL POWER, WESTERN CANADA 1955



The first and most widely discussed is Southern Ontario. There, by the early 1960's, the rising demand for electrical energy will have largely outstripped the available hydro-electric resources of the province. More thermal power stations will have to be built in any case. The question then arises as to whether it will be more economic to supply the base load portion of these needs by building nuclear reactors, or by turning increasingly to the use of coal imported from the United States.

The indigenous fuel resources of Ontario are limited. Natural gas, a premium fuel, is unlikely to be used extensively for power generating purposes. Other users will also pay more for residual oil. Hence oil in sufficient quantities is not likely to be available to Ontario Hydro. This leaves the



RESERVES AND CONSUMPTION OF ELECTRICAL POWER, EASTERN CANADA 1955

market to coal. Laid down at Toronto or Windsor for about $9 a short ton, it can be burned to produce electrical energy close by the region's principal load centres for less than six mills per kilowatt-hour. This is the minimum target which our medium-large nuclear energy plants will have to achieve if they are to be truly competitive with other sources of power in central Canada.

Competitive is hardly the right word. A coal-fired thermal plant, capable of operating as a base load facility in its early years, can later be relegated to an intermediate and, finally, to a peak shaving role. As it ages, it gives way to progressively more efficient and, presumably, more capital intensive coal-burning plants of like kind. In this way, a conventional coal-fired system is able to accommodate itself to continual improvements in equipment, operating techniques and fuel utilization efficiencies.

Nuclear power plants, on the other hand, enjoy no such advantage. Being expensive to construct and, at the same time, comparatively light on fuel, there is little to be gained by shutting them down. Their initial role, in other words, is their continuing role. As far as the power utilities are concerned, the expectation of substantial improvements in design (which would undoubtedly lead to a further reduction in capital cost) could provide grounds for postponing their construction. Deterrents such as this, while they will fade into the background when the investments associated with the construction and equipment of nuclear power plants more nearly approximate those of conventional thermal stations, will tend to delay what might, otherwise, be a much more rapid upsurge in the production of nuclear power in this country.

The next most plausible region for the application of nuclear power is the Maritimes. Except for a number of sites on the St. John River in New Brunswick, most of the water power resources of the Maritime provinces have already been harnessed. Resort will therefore have to be made, and made increasingly, to thermal power in order to meet the growing requirements of electricity in this region of eastern Canada.

Nuclear power stations offer possibilities, mostly on grounds of cost. Domestically produced coal is difficult to mine and expensive to haul to the principal centres of power consumption. The supply of residual oil from the local refineries is limited. Natural gas is out of the question and a suitable method whereby local oil shales may be burned to produce power at competitive prices has yet to be developed. Leaving aside, for the moment, the possibility of using imported fuel oil, an average cost of around eight mills per kilowatt-hour is, perhaps, the best which can be expected, using fuels which are indigenous to this region.

While cost considerations may eventually favour the establishment of a nuclear power source in the Maritimes, demand factors are not so encouraging. Most of the present day markets are widely dispersed and existing utility systems, lacking useful interconnections, have accumulated a certain amount of plant which would be surplus to the needs of a more highly integrated Maritime power grid. Meanwhile, prospective increments in demand will remain small relative to those of southern Ontario. This, together with the highly variable and, hence, less favourable load characteristics of the individual utilities, tends to postpone the day when large-to-medium sized nuclear power plants will be chosen in preference to steam stations of the conventional type.

Any plan leading to the rationalization of these various power systems could, however, change this picture considerably. The region's power growth base might thereby be extended to cover most, if not all, consumers in Nova Scotia and New Brunswick. It could also take in northern Maine and neighbouring areas in Quebec as well. The annual increments in the

demand for firm power would then be more compatible with the capabilities of a large-to-medium size atomic energy station. The building of new coal fired steam plants could be postponed for a time. And the supply of electricity coming from New Brunswick's remaining hydro resources could be used, as and when it became available, both for base load purposes during the months of greatest runoff and for peaking purposes during the remainder of the year. In this way, a fully integrated Maritime power grid might inherit the best of all possible worlds—water power, coal, and nuclear fuel fired stations all being used more or less concurrently in the servicing of the growing power demands of the region as a whole.

The availability of cheap residual oil, shipped in by tanker, complicates this situation. During recent years, black oils produced in foreign refineries have been offered at prices substantially below that of the domestically mined coals. This, in the last analysis, is the sort of competition which our centrally located base load type nuclear power plant will have to meet. Seven mills per kilowatt-hour might be taken as a rough approximation of the cost of power produced at a number a seaboard locations using this imported fuel. At an equivalent price, nuclear energy is, no doubt, to be preferred. The landed price of residual oil fluctuates, more or less, in line with changing tanker freight rates. Nuclear energy, being less susceptible to dislocation in time of war or shortages of shipping, is therefore to be preferred on grounds of reliability.

Next, let us turn to southern Manitoba. In the eastern Prairie region, consumption of electric power is increasing in a manner more compatible with the size and nature of the nuclear power plant which we have in mind. Yet competition will be keen. Extensive hydro-electric resources, amounting to several millions of kilowatts, remain to be harnessed in the northern and central sections of the province. Fuel, in the form either of natural gas or lignite coal, can also be delivered—and delivered at moderate cost—to steam stations close by the main load centres. The delivered price of base load power rather than long run supply limitations is therefore likely to be the principal determinent of feasibility in southern Manitoba.

Events, in the form of a steady increase in demand, are likely to decide this issue within the next decade. Though several stations are already under construction, others will be required to effect a doubling in output by 1965. If fresh water powers are to be developed, this means going north. It means heavy initial investments in dams, storage facilities and long distance transmission lines. Once a heavy capital investment programme of this kind has been initiated, there will be little incentive to look back. Economies stemming from the more intensive use of the earlier and, generally speaking, more expensive construction projects will render more attractive subsequent water power projects on the Saskatchewan and Nelson Rivers. Because of this and because of the increased use of storage for steam regulating purposes, a growing proportion of this power will be continuous in nature. In other

words, the early utilization of these hydro resources could postpone for many years the use of nuclear energy in the eastern Prairie region.

The alternative, and this is perhaps only a matter of degree, is steam power. Using presently available fuels, a 100 thousand kilowatt steam station can now be built close to Brandon or Winnipeg to produce electricity for under six mills per kilowatt-hour. Later, as other capabilities become available, it could be used in supplementary fashion. It could be employed to firm up the water powers run in from the north. It could be used in conjunction with even more efficient steam plants built at progressively later dates. And, finally, it could be used for peaking purposes in conjunction with atomic energy. A nuclear power plant could do none of these things. Therefore, only under circumstances where atomic energy can be made available at five mills per kilowatt-hour or less, is there any likelihood of it playing a useful mid-term role in southern Manitoba.

Having discussed the several utility areas in which nuclear power stations may be competitive, let us review, in summary fashion, the circumstances as we find them elsewhere in Canada.

As far as British Columbia is concerned, water power should be the principal source of electricity for many years to come.[4] The harnessing of many suitable sites within the province, together with the possibility of substantial imports resulting from storage benefit settlements with producers downstream in the United States, points to a surplus of electrical energy lasting into the 1980's or even longer. Power costs will also be low relative to those in other areas which we have discussed. In order to be considered at all, base load thermal power will have to be available at five mills per kilowatt-hour. These are the main reasons why the utilities in British Columbia are less likely than those elsewhere to derive real benefit from the development of atomic power.

In the western and central Prairie regions, on the other hand, fuels are both plentiful and exceptionally cheap. Coal can be strip mined and converted into electricity for about four mills per kilowatt-hour. Even at that, natural gas is to be preferred in many places. Large steam stations of more or less conventional type, supplemented in western Alberta by water power and elsewhere by the use of natural gas burning gas turbines, are consequently expected to meet most, if not all, of the growth in the demand for electricity in Alberta and Saskatchewan.

The situation in Quebec is, in some ways, analogous to that in British Columbia. Several exceptionally large power resources have yet to be developed at moderate cost in the vicinity of Montreal itself. Other developments, promising a laid down price of electricity in the vicinity of five mills

[4]The amount of hydro power (and certainly the timing of its availability) is, of course, contingent upon international developments with regard to storage and the solution of the fish problem as it affects power dams.

per kilowatt-hour, remain to be launched on a number of rivers flowing southward and eastward into the Gulf of St. Lawrence or north and westward into Hudson Bay. Indeed, it may be 20 or 30 years before these projects, together with the introduction in the intervening years of peaking plants burning coal or residual oil, have exhausted all of the advantages inherent in producing electricity by present day means.

Elsewhere in Canada (and this includes the Yukon, the Northwest Territories, and Newfoundland), the utility systems are in their infancy. Either they rely on diesel engines as their prime movers or they purchase their supply of electrical energy from large wood or mineral processing industries whose activities are dependent, to a greater or lesser degree, on the availability of cheap hydro-electric power. Besides, their increments in consumption are small and load factor considerations, because of the tremendous variations in ordinary residential and commercial demands, tend to rule out the use of nuclear energy in their case.

Having discussed the pros and cons of nuclear power—at least as they relate to the more highly developed power utility areas across Canada—let us now turn to particular industrial applications. Let us look more closely at the needs of those types of manufacturing activity which might, for want of a better term, be called resource-oriented. Their locational bias is towards a cheap source of energy, towards a ready supply of raw materials, or both. They include, by reason of similarity of techniques and the dependence upon a continuous supply of low-cost electricity, the processing of goods imported in their primary form.

The first industrial application which comes to mind is aluminum. As anyone familiar with Canada's economic development is aware, the electrolytic refining of this metal is already being carried out in this country on a considerable scale. Why is this? And why is further expansion in this direction deemed likely? Exceptionally cheap power close to tidewater is the answer. Low-priced electrical energy, together with the advantages of low-cost transportation to and from the refinery sites, has over the years been more than sufficient to offset the pull of the market when it came to selecting this industry's locale.

As long as water powers in excess of one millon kilowatts and capable of supplying electricity at three mills per kilowatt-hour or less remain to be developed in Canada, there is little chance of nuclear energy taking over this role. In time—and this may take several decades—the cost differential between that associated with the harnessing of these resources and that of treating the bauxite and refining the aluminum elsewhere, may be narrowed to the point of extinction. Then, in Canada's case, the growth possibilities of the aluminum industry itself may disappear. Exceptionally cheap power, produced by nuclear means, at or close to the principal markets for aluminum products, may preclude a further increase in ingot production in this country. Bauxite mined and treated in the tropical areas of the world,

could then move, not to Canada, but to the eastern United States, the United Kingdom or Western Europe for further processing. One might even conclude that, if the scientist and the engineer are eventually successful in driving atomic power costs down to a figure of, say, four mills per kilowatt-hour, they would effectively, have put an end to what has, heretofore, been one of Canada's great natural advantages—that is, the use of low-cost water power for the production of light metals.

Much the same sort of thing may be said about the prospects for one or more custom smelters located either on Canada's eastern or western coast. It certainly would not pay to bring raw materials from other countries to these areas for electro-processing unless favourable power costs were to dictate otherwise.

Fortunately for Canada, certain of these electro-metallurgical and electrochemical industries are resource-oriented for reasons other than a minimum cost of electricity. Mineral concentrates are often produced in large tonnages. Since their bulk may be reduced considerably by smelting and refining at or near the mines, it is sometimes preferable to develop power locally rather than to transport these concentrates to other centres which might enjoy a competitive advantage in so far as the cost of power itself was concerned.

What applies to some does not necessarily hold for others. Extensive medium-to-low grade base metal deposits are at one extreme. Much is to be gained by their on-site processing. Transportation charges are thereby reduced to a minimum. Besides, other metal values and a number of chemicals can be sold as useful by-products to such an operation. Iron ore lies at the other. Because of the much greater efficiency of the blast furnace as opposed to electric smelting and due to the pull of the market where other ingredients including coking coal and steel scrap are readily available, there is little to be said for the conversion of iron ore into pig iron or steel at, or close to, the mines themselves.

In between, we have a long list of minerals, deposits of many of which have already been discovered in this country. What are the prospects for their electro-processing in Canada? The noble metals, particularly copper, can be smelted without the use of electricity and shipped considerable distances in blister form. The steel-alloying elements like nickel, cobalt, and manganese, depending to some extent on the complexity and grade of the ore in question, can also be moved hundreds of miles, economically, in concentrate form. Even titanium can be reduced and exported as a titanium rich slag without making exceptionally heavy demands on power. It will only be in circumstances where the price of certain of the lesser known metals—and this applies with some force to titanium—has been reduced considerably and their sales have reached into tonnages commensurate with aluminum, that processing aimed at producing the metals

themselves will reach a scale worthy of the installation of large electric power generating facilities.

Should isolated industries of this kind develop in the northern or Canadian Shield country of Ontario, Quebec or Labrador, cheap hydro power will be available, and available in quantity. The same is true of refineries which may be constructed in the Western Cordillerian region of British Columbia and the Yukon. Should they spring up in northwestern Ontario or draw on mines in that portion of the Canadian Shield which also fringes on the great Prairie region of Canada, they will have natural gas to choose from. Chemical processing techniques, depending essentially on the metal content and complexity of the ores themselves, could eliminate the need for electrolytic refining altogether. Indeed, if recent developments are any guide, there will be a strong tendency for a number of mineral concentrates (more particularly those containing nickel and cobalt) to move to the gas fields for treatment. Nuclear energy for these purposes, therefore, find little application in what, until recently at least, have been the principal metal producing areas of Canada.

Yet, there can be exceptions. The Maritime provinces, as we have noted previously, are handicapped by a lack of cheap electric power. Now that extensive base metal deposits have been discovered in the vicinity of Bathurst, the problems centring around their further processing are receiving a good deal of attention. Will it, for instance, be cheaper, after mining and concentrating these ores, to ship them elsewhere for treatment? Or should certain of the bulkier products be treated electrolytically close to the mines themselves?

The lower the cost of power, the more there is to be said for on-site processing. Yet charges as high as six mills per kilowatt-hour could, perhaps, be tolerated. This might be true in instances such as the refining of lead where the outlays for electricity are not a major determinant of the cost of the refined product itself. The manufacture of by-product chemicals is even less dependent on the price of electricity. Electricity in this cost range would not seriously inhibit its development. In fact, present indications are that operations along these lines may, collectively, require a block of firm power in excess of 100,000 kilowatts. A combined electro-metallurgical and electro-chemical centre, located in northern New Brunswick, may therefore offer what may well be one of the first opportunities for the nation's newborn nuclear power industry to assist in the establishment of other and quite different types of economic activity in this country.

Nothing has, as yet, been said about the tremendous amount of by-product heat which will be available from these future power plants. Could not this also be turned to some useful purpose? The obvious place to look is at those resource processing industries which are purchasers both of electric power and of fuel for the production of steam. Canada's largest single industry—that of the manufacture of pulp and paper—immediately

comes to mind. The average Canadian paper mill (and there are over 120 of them) requires 30,000 to 40,000 kilowatts of installed capacity. It operates at a high load factor. It may also consume, each year, as much as 100,000 tons of coal or coal equivalent fuels for use in the grinding, cooking and digestion of wood during the course of its conversion into pulp. In serving demands of this kind, the cost of nuclear power, in the form of electricity is, by no means, our only measuring rod. Some credit should also be allowed for the reactor's output of sensible heat. The latter, in bonusing the whole operation, might conceivably permit the installation of economic multi-purpose plants in what are today the relatively high-cost fuel areas of the country.

Applications of this kind merit further study. This is particularly true of those, as yet, undeveloped forest regions of Canada where suitable wood and wood transporting facilities are available and where electric power might otherwise tend to be expensive or in short supply. New forest limits in Nova Scotia, New Brunswick, along the north shore of the Gulf of St. Lawrence and possibly in northern British Columbia might eventually be brought into production as a result of developments of this kind.

So much for the regional application of medium-to-large sized nuclear power plants. What about the much smaller 2,000 to 3,000 kilowatt installations which were mentioned at the outset? Where may they fit in? Obviously, if they are to have any commercial applications, they must be built to serve much more modest demands. Even though their service may still be confined to that of a base load function, they will have to be used in lieu of diesel electric plants. Why? Because this is the scale of power production which, until now, has been best served by that highly versatile jack of all trades, the internal combustion engine.

Present indications are that nuclear power cannot be produced in such small quantities for less than, say, 20 mills per kilowatt-hour. This, immediately, rules out many parts of Canada. It leaves out, as being too expensive, those locations where diesel fuel can be brought in at a cost of less than 20 cents a gallon. It also leaves out of account those types of activity which vary considerably, throughout the day and from month to month, in their demands for electric power. Essentially, the circumstances narrow down to the large mining communities which are developing in the far north. Their location in turn freed from the difficulties associated with overland transportation and great distances by a nuclear source of electricity and by-product heat, may thereby be allowed much greater scope as the years go by.

In summary, and supported by an analysis of future demands, category by category, and area by area, our working data points to certain highly generalized conclusions, they are to the effect that:

(a) fifty or more medium-to-large, 100,000 kilowatt nuclear power plants may be required in Canada by the late 1970's or early 1980's.

The majority of these will be located in Southern Ontario. Others may however, be needed in the Maritimes and possibly, southern Manitoba;

(b) stations of an intermediate size may prove to be a useful source of energy in industries like the manufacture of pulp and paper where advantage can be taken of their capacity to produce by-product heat. Mill locations which could benefit from such a multi-purpose approach might eventually be found in the Maritimes, on the east and west coasts and possibly in some of the more northerly and remote parts of Saskatchewan, Manitoba, Ontario and Quebec;

(c) the number of instances where 2,000 to 3,000 kilowatt nuclear power plants are required is liable to be much greater. Yet these smaller multi-purpose installations may make only modest contribution to the nation's over-all energy requirements. Generally speaking they would be of use in Canada's far north.

11

OTHER ENERGY SOURCES

Section I: Fuelwood

No study of energy in Canada would be complete without reference being made to the important role played by wood as a source of heat. As recently as 1940 more wood was used in this country as firewood than in the production of pulp and paper. Even today the number of cubic feet devoted to the purpose of supplying energy amounts to approximately 15% of the total volume of wood cut for all purposes.

Most of this material is used for space heating. In some areas, however, it is employed extensively in the form of wood wastes for steam raising in industry. From the limited information available, its appears that the total amount of energy obtained annually from the nation's forests is about the same as that which could be obtained from three to four million short tons of bituminous coal. Though the total amount has been declining for many years, wood fuel in all forms still meets approximately 5% of the nation's total energy requirements.

Wood was the principal source of fuel and power energy in Canada up until the beginning of the present century. The following table indicates the dominant position which it occupied in the 1870's and 1880's. Before the turn of the century it began to be displaced by the fossil fuels for industrial use and for space heating purposes in the principal cities and towns of central Canada.

Wood, being available in many parts of Canada, played an indispensible role in the days of early settlement. Other energy sources were widely scattered. Their extensive utilization therefore had to await the development of adequate means of transportation. Fuelwood, by contrast, cannot be moved economically for more than a few hundred miles. Yet the fact that some 750 thousand Canadian households still rely primarily on wood as a source of comfort heat illustrates the continuing commercial worth of local supplies. In several provinces, notably Quebec and New Brunswick, fuelwood is still a major source of energy. Statistics taken from the 1951

census indicate that, outside of Montreal, 60% of all the households in the Province of Quebec still depended upon fuelwood for cooking and space heating.

Relative Importance of Wood as a Source of Energy
Canada, 1870-1955 by Decades

Year	Contribution in Terms of: Millions of equivalent cords[a]	Millions of cubic feet[a]	10^{12} B.t.u.'s	Percentage of total energy consumption
1870	8.7	696	175	85
1880	11.0	880	220	77
1890	10.5	840	210	57
1900	9.3	744	186	39
1910	12.4	992	247	26
1920	9.3	744	186	16
1930	11.0	880	220	16
1940	10.5	840	210	13
1950	9.5	760	190	8
1955	7.3	584	145	5

[a]Includes an allowance for such mill wastes as slabs, edgings, shavings and sawdust.
SOURCE: Volume figures adapted from *Census of Canada* data; 1955 estimated.

The wood used as fuel in Canada is mainly either round wood cut specifically for fuel purposes or mill wastes obtained as a by-product of mill operations. The latter consist of slabs and edgings, lumber trimmings, shavings and sawdust left over from the manufacture of logs into planks and boards. Most of the cordwood is cut on farm woodlots. Accounting for some three-quarters of the total as recently as 1950 it has declined steadily in amount. Meanwhile the volume of wood fuel produced by the nation's sawmills has shown greater stability. Though greater quantities have been diverted to pulp and paper production, the steady rise in Canadian lumber output has resulted in considerable amounts of mill wastes being offered to householders and to other industry as wood fuel.

The total volume consumed in Canada can only be approximated at best. This is because a large (and increasing) proportion never enters commercial channels and is therefore not subject to measurement. Much of the cordwood cut on farm woodlots is also consumed by the farmers themselves. Similarly, a growing proportion of the mill wastes is being consumed by the firms or plants within which they originate. Difficulties encountered in gathering production statistics from innumerable sources and a lack of uniformity in reporting are among the reasons why no reliable series, such as exists for coal or electricity, is available on the volume or value of wood consumed as fuel in Canada.

Because of these deficiencies, an attempt has been made, where possible, to relate the consumption of wood to such other statistical series as are

available on space heating and other wood-using equipment in use in Canada. Indeed, the numbers of household heating units employing wood are perhaps the best measure of the volume of wood employed for space heating purposes in recent years. Where possible, information on supplementary heating and cooking equipment has also been collected in an attempt to build up rough estimates of the total amount of wood utilized in this way.

The total number of Canadian households reporting wood as their principal fuel shows a 40% decline between 1941 and 1956. By far the greatest drop has occurred since 1951. On the assumption that the average Canadian household utilizes 175 million B.t.u.'s per year for space heating and cooking purposes, domestic consumption amounted to better than 10 million cords (equivalent) in the early 1940's, around eight million cords in 1950, and approximately six million cords in 1955. From available data on equipment in use in commercial and institutional establishments, it has been assumed that an additional 1.5 millon cords is probably employed in the other sectors of the economy.

Households Reporting Wood as the Principal Fuel

(thousands of households)

	1941	1951	1956
Total households in Canada	2,576	3,409	3,974
Those burning wood[a]	1,183	951	724
Wood as % of total	46%	28%	18%

[a]Excluding sawdust which is used by about 35,000 households.

Returns pertaining to the total volume and value of fuelwood purchased by the nation's various manufacturing plants are available, from the annual census of industry, year by year, back to 1926. Like the quantities used by Canadian households these amounts also show a steady long-run decline. From better than 720 thousand cords in the mid-1920's, they have since fallen to something in the order or 300 thousand cords annually. This trend, which appears to be slowing down, is traced out in the following table.

Fuelwood Purchased by Manufacturing Establishments, Canada, 1926-53

	1926	1929	1935	1939	1948	1953
Quantity in thousands of (equivalent) cords	722	656	550	475	309	300

Besides purchased wood, a considerable volume is used directly by the consuming industries themselves. The sawmill industry alone currently employs the equivalent of over a million cords. An incomplete survey carried out a few years ago recorded a minimum of 1.3 million cords

utilized, either as mill waste or in the form of cordwood by the forest industries themselves.

Such mill wastes as are marketed are sold in the form of slabs and edgings. In British Columbia, where this practice is most common, large amounts of sawdust and hogged fuel[1] are still used for steam raising as well as space heating purposes. In the 1951 census it was reported that approximately 35 thousand sawdust burning units were in operation in that province, and annual sales of sawdust in that year were equivalent to about 350 thousand cords of wood.

The future trends in the fuel use of mill-wastes is probably downward. Since mill-waste is largely a by-product of lumbering operations, and since lumber production is expected to increase by as much as 50% over the next 25 years, the available supply of mill left-overs may rise proportionately. Some of it could be converted into small dimension stock and used in the production of wood products other than lumber. An increasing amount may also be manufactured into pulp or converted into fibre boards, chip-boards and other sheet building materials. A continuing decline in the price of alternative fuels and the growing market for the more highly processed forest products would reinforce this trend.

Pulp mill wastes may also be used to a greater extent for the production of heat energy. Lignin constitutes about 30% by weight of the average northern softwood species of tree. Chemical pulping, in extracting this and other combustible carbohydrates, may leave as little as 50% of the original pulpwood log behind in the form of cellulose fibres. The resultant liquors can only be employed in modest amounts by other chemical process industries. The only practical alternative to their rejection is therefore to convert them into a usable form of energy. Because of the increasing use of chemical methods of pulping, and the added incentive in more remote mill locations to produce heat energy by other than conventional means, research in this direction may add appreciably to the production of heat energy from such pulpmill waste products.

Meanwhile there is good reason to believe that the production of wood cut primarily for fuel purposes will continue to decline. One of the contributing factors will be a shortage of manpower in the woods. A relatively high and rising real price for pulpwood and sawlogs will, at the same time, divert more production from the woodlots to industry. Only in circumstances where fuelwood can be sold at premium prices for occasional use in summer cottages, home fireplaces and outdoor grills will this trend be arrested.

There seems little reason to doubt that the number of households burning wood will be fewer than at present. However, by reason of its availability

[1]Hogged fuel is produced by feeding larger pieces of mill-waste into a hog or refuse chipper to reduce them to smaller sizes which may be machine-fed to furnaces.

Household Heating and Cooking Equipment in Canada, 1941, 1951, 1956

(thousands of households)

	1941	1951	1956
Principal heating equipment			
Coal / Coke	1,206	1,469	1,026
Oil	67	775	1,843
Wood	1,183	951	724
Natural gas	87	163	333
Other	32	51	48
Total	2,575	3,409	3,974
Cooking equipment			
Coal	238	1,485 (Coal and Wood)	1,099 (Coal and Wood)
Wood	1,276		
Oil	42	179	214
Natural gas	—	724	822
Electricity	1,019	976	1,797
Other	—	—	20
Total	2,575	3,364	3,952
Supplementary heating equipment			
Coal / Coke	—	165	234
Oil	—	114	156
Natural gas	—	—	60
Wood	—	206	436
Other	—	53	68
Total	—	538	954

SOURCE: Census of Canada, 1941 and 1951; *Household Facilities and Equipment*, D.B.S., 1956.

in northern and more remote areas and for farmers and mill operators, because of its low cost, there may be from 200 to 300 thousand households dependent on this source of energy in the late 1970's and early 1980's. When industrial uses are included, total consumption 25 years from now may be in the order of between two and three million (equivalent) cords of wood. This is less than half of the seven million cords[2] estimated to be employed in

[2]See also *Progress in the Development of Energy Resources of Canada*, a paper prepared by the Dominion Coal Board and Department of Northern Affairs and National Resources and presented at the Fifth World Power Conference. The Coal Board series on fuelwood consumption declines from approximately 11.2 million cords in 1945 to 8.5 million cords in 1954.

1955 for the production of heat. Contrasted with our estimates as to the nation's total energy requirements, we therefore may see the fuelwood declining from a position of supplying approximately 16% of Canada's total energy requirements in the mid-1920's to 5% in 1955 and approximately 1% a quarter of a century from now.

Section II: Tidal Power

The physical feasibility and economics of producing hydro-electric energy from the tides has received serious, though intermittent, attention in various parts of the world. Several sites, the majority of them in Western Europe, have been harnessed on a comparatively small scale. Interest in North America, on the other hand, has centred on the high tides and peculiar land features which characterize the Bay of Fundy especially along the State of Maine and New Brunswick coasts. Foremost among these has been the Passamaquoddy Tidal Power Project—a series of dams, locks and storage reservoirs, the construction cost and operating characteristics of which have periodically been under discussion between Canada and the United States since the early 1920's. To date its economics have not been proven favourable. Another—an all-Canadian project on the Petitcodiac and Mamramcook Estuaries in New Brunswick—has also been investigated although the results have been even less encouraging.

Recently, as a result of expressed interest by the State of Maine, the possibilities of an international venture at the mouth of the St. Croix River has been revived by the United States authorities. A thorough investigation of both the engineering and fisheries aspects soon will be carried out under the auspices of the International Joint Commission. The United States Congress has voted $3 million for this purpose. Canada has earmarked $300 thousand with the proviso that this be confined to a study of the fisheries aspects—a matter of considerable anxiety to fishermen operating in the Bay of Fundy. No commitment as to the completion of these or any related works has been made in either country. Further decisions, as to the construction, await the completion of these investigations and a thorough-going appraisal of the economic merits of such an international power project.

Since the results of this proposed investigation will not be available for several years, an expression of opinion as to its economic merits is premature. However, reference to past findings may be useful. The report of the United States Federal Power Commission dealing with this matter and issued in March, 1941, concludes that "the Passamaquoddy Power Project cannot compete successfully with river hydro-electric power potentially available to the State of Maine, or with power from modern steam-electric plants". The Commission's experts go on to show that, even "under the most favourable conditions of financing, (*i.e.*, 3% interest on loans and no allowance for the payment of income tax or insurance), the average cost of electricity would be in the vicinity of 7 mills per kilowatt hour. The

corresponding switchboard costs of energy of the same class, and amount from a conventional steam-electric plant was found, at that time, to be about 4.5 mills per kilowatt hour".

Other complications were mentioned. Since the peak availability of tidal power varies from day to day, it must be firmed up with other generation. Thus supplementary steam or river hydro capacity would have to be built. These facilities together with the tidal power installation would cost a great deal. Not only that, but the quantity of energy which they were potentially capable of producing appeared to be well beyond the foreseeable requirements for electricity either of the northeast corner of the State of Maine or of the Province of New Brunswick.

Reviewed by the International Joint Commission in 1950, the reporting Engineering Board stated that in its opinion, "the International Passamaquoddy Tidal Power development could be feasibly engineered, constructed and operated." However, the Board emphasized that "many of the engineering problems are unprecedented anywhere in the world, and their solution will require a great deal of costly foundation exploration, field surveys and engineering analysis."

Conditions in the Petitcodiac and Memramcook Estuaries appear to be even less favourable economically. In their report issued in 1945, the Engineering Branch of the then Department of Mines and Resources reported the resultant power cost to be in the vicinity of 55 mills per kilowatt-hour. This was many times the figure of seven mills estimated for steam-electric generation alone. Capacity in this case was estimated to be 280,000 horsepower; the load factor 61%, the total capital cost $155 million and the rate of interest 3.5%.

On the market side, circumstances are changing. The quantity of power required over the next 10 or 15 years is much larger than that envisaged even in the early 1940's. Yet, the same reservations as to cost remain. We can only conclude from the information supplied in these reports that the economics of supplying hydro-electric energy from the most favourable tidal sites in Canada are, as yet, unproven. Even were the Passamaquoddy Power Project to be built and its output shared equally with the United States, its contribution to Canada would be less than that of a single large scale (500,000 horsepower) river hydro or steam-electric power installation. Thus, the part which tidal energy is likely to play in the total Canadian power picture can be assumed to be nominal, if not disregarded, during the period between now and 1980.

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Note

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Section III: Solar Energy

Nuclear energy, as we have seen, offers considerable promise for the future. Yet it has certain limitations. Those stemming from the need to employ highly trained personnel, the costly nature of much of its plant and equipment and—more significant still—its market selectiveness will condition its usefulness. This is also why the major impact of atomic power may be confined to the more highly developed areas where energy costs are on the increase and where both investment capital and industry are available to assist in the financing, operation and maintenance of large and complicated stations of this kind.

Solar energy holds out hopes in quite a different direction. It falls on cheap waste land just as abundantly as on builtup areas in the nation's larger cities and towns. Solar operated devices can (and indeed must) be small in size.[3] Properly conceived and constructed, they require little attention and can be installed wherever the need arises. In contrast to that produced using nuclear fuels, solar heat and power are therefore likely to be more competitive in other parts of the world where individual demands are modest, conventional fuels must be imported, capital is scarce and where industrial skills are either lacking or difficult to obtain.

This is not to imply that solar energy is likely to be cheap energy. Even in the most modest installations, a good deal of collecting, storage, plumbing and other equipment is involved. Its very unpredictability also

[3]Because of the amount of collecting and other equipment involved, it is doubtful whether solar energy for the production of electricity would be economic in units in excess of five to ten horsepower.

tends to make it more expensive. Costly storage devices or, alternatively, duplicate facilities capable of providing energy from other sources become necessary to ensure continuity of supply. Because a full complement of equipment will be needed to supply this supplementary energy on a stand-by basis the over-all cost will, in most Canadian circumstances, be excessive.

There are uses in which the intermittent and variable nature of solar energy is not so serious a handicap. One is the pumping of water for irrigation. Another is the purification of brackish water by distillation. Arid conditions and long, uninterrupted period of sunlight frequently go hand in hand. Hence, in a few areas of western Canada where the summer sun shines intensely, some advantage may directly be taken of this comparatively abundant and yet difficult-to-harness form of energy.

For various technical reasons, which bear directly on the economics of solar energy utilization, the conversion of solar energy into power is at present less attractive than the simpler conversion into heat energy to be supplied at such temperatures as can be used in space heating. Such applications as the space heating of buildings are not at present economically attractive since storage or standby equipment must be provided.[4]

There exists the possibility of using solar energy as a supplementary source of heat for buildings, through the provision of large glass areas. Even this is not without difficulty and may frequently add to, rather than decrease, the home or office owner's fuel bill. When the sun is at its height, rooms with a southern exposure tend to be overheated. This calls for a system of air conditioning or at least air circulation. When the sun is not shining, heat losses occur which are several times those through a properly insulated wall. Thus it is to such lesser applications as water heating in summer or the activation of yet to be fully developed devices like solar batteries[5] that we must turn in order to list a few of the more likely, and possibly widespread, applications for the future.

The intensity of the sun's rays, obviously, has a good deal to do with solar energy economics. Measured in terms of coal equivalent, the average daily rate in summer in the arid sub-tropics is about 3.7 tons per acre. The maximum rate may reach five tons on a clear dry day in June. The average for the whole of the United States is just over two tons of coal equivalent per acre per day. This illustrates both differences in latitude

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[4]The critical line, north of which solar energy cannot be relied upon exclusively for comfort heating passes midway through the United States. It therefore not only excludes New England, the north central states, the Dakotas, Montana and most of the Pacific Northwest, but all of Canada as well.

[5]The direct conversion of sunlight into electricity by photo-voltaic cells has been under investigation for some time. In 1954, a solar battery, employing purified silicon gave encouraging results. Though prohibitive in cost at the present time, some such device as this may eventually be used to equip amplifier stations in rural telephone lines, etc.

and the variations introduced by cloudiness and other regional climatic factors. In Canada at the 49th parallel, 1.5 tons may be a maximum.

The fact that little development in the uses of solar energy in man-made devices has yet taken place in areas where sunshine is relatively more abundant supports the view that the direct contribution to be made by solar energy to Canada's heat and power requirements by other than existing natural means will be of minor proportions at least over the next 20 to 30 years.

Indirect collection of solar energy is something else again. Heat pumps, though not commonly referred to in these terms, are already in use as refrigerating and summer air conditioning machines. Since such machines are essentially devices for pumping heat from one temperature level to a higher one at which it can be rejected, they can be used for heating as well as cooling. They are usually electrically driven. The power required depends upon the difference in temperature levels through which the heat must be pumped, but can, under favourable circumstances, be as little as one-quarter or one-sixth of the total heat discharged.

Some 20 heat pumps are already in use for house heating in Canada, extracting heat from the ground with a consumption of electrical energy for pumping of about 40% of the total heat delivered. There could be technical advantages in combining such heat pumps with solar energy collection and storage systems as the source of heat. Such an arrangement would permit improved solar collection efficiencies and an easing of heat storage requirements for the solar energy system as well as reduced pumping costs for the heat pump system.

Electrical energy available at one-half cent (5 mills) per k.w.h. for direct space heating in conventional electric heaters is competitive with domestic furnace oil at 17¢ a gallon. Although available at this low rate for some purposes in Canada, its use for space heating has not been encouraged. Using the heat pump alone, the power consumption might be reduced to one-third, thus providing the same energy cost with electrical energy at 1.5¢ per k.w.h. but this would also call for a capital investment in equipment amounting to two to three times that of a conventional heating system. The combination of a solar energy system with a heat pump might decrease power costs still further, but only at the expense of further complexity of the over-all system. Such developments, though ultimately possible, are not likely to be economically attractive in the near future.

Meanwhile we may continue to witness what has been going on for several generations. Indirectly, through natural evaporation, rainfall, river basin accumulation and the harnessing of water power, the sun's energy has been and will increasingly be put to work in the production of large quantities of hydro-electric power. As far as Canada is concerned, such indirect rather than direct applications are likely to constitute solar energy's

principal contribution to the heat and power needs of the economy over the next quarter century.

Note

At most, there are two dozen solar heated houses on this continent at the present time. With one or two exceptions, they are located in the southwestern United States.

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PART C

ENERGY AND CANADA'S ECONOMIC PROSPECTS

12

INTER-FUEL COMPETITION IN THE MAIN ENERGY CONSUMING REGIONS OF CANADA

PART B of this study has been concerned with the prospective supply of and demand for the different sources of energy in Canada. Though geographical factors have been taken into account, no attempt has previously been made to discuss competition between the different fuels, province by province, across Canada.

In order that this aspect of the study could be completed on time our inquiry was reduced to its simplest terms—that of delineating the principal areas of competition and, on the basis of interviews with provincial, industrial and other authorities deciding how the requirements of each region would best be met in the mid-1960's. Longer run forecasts were ruled out on the grounds that past trends, in this case, could not be employed as a guide to the future.

By limiting the appraisal to uses in which the different fuels compete directly one with the other, motor vehicle requirements were automatically excluded. Similarly electricity, because it does not usually compete directly with the fuels, was also excluded from the survey. (It should be noted, however, that the regional demands for electricity have been considered at length in Section II of Chapter 10.)

In attempting to forecast the likely fuel mix major region by major region across Canada, we have therefore confined ourselves to an assessment of such energy requirements as could for all practical purposes be supplied by either coal, oil, natural gas or fuelwood. The principal uses examined in detail are mining, manufacturing, domestic and commercial space heating, railway usage and the generation of electric power by thermal means. The regional breakdown consists of Ontario, Quebec, British Columbia, the Prairie Provinces and the Atlantic Region of Canada in that order.

Ontario

Ontario leads all other provinces in the amount of fuel it consumes. Indeed the quantity of coal, oil, natural gas and other fuels sold there each year exceeds by nearly one-third that purchased in Quebec, the Maritimes and the Province of Newfoundland combined.

While the total has been rising steadily, statistics pertaining to the different fuels show a decided preference for oil.

Consumption of Fuel in Ontario[a]

(millions of tons of coal equivalent)

Year	Coal	Oil	Gas[b]	Wood	Total
1941	16.0	1.7	0.9	1.5	20.1
1953	17.6	6.2	1.4	0.6	25.8
1965 est.	13.0	12.4	7.0	0.4	32.8

[a]Exclusive of highway use.
[b]Natural and manufactured gas.

From this it can be seen that coal is still the dominant fuel. However, the amounts purchased have recently begun to level off. Oil, meanwhile, has continued to gain both absolutely and relatively. Together with natural gas it has accounted for all of the increase in fuel consumption which has taken place in Ontario in the postwar period.

Coal has suffered most in two sales categories: space heating and on the railways. In both, the drop in sales since 1946 has been in the order of two million tons. More recently, the amount used for the production of manufactured gas has also been curtailed. The greatest strength has come from a new quarter—namely, the production of electric power. More than one million tons of coal were burned for this purpose in 1955. Steel production is also on the increase, thereby augmenting the demand for metallurgical grades. Meanwhile coal is roughly holding its own in secondary manufacturing.

In contrast to coal, oil consumption has been rising on all fronts. The amount sold for space heating has risen more than sixfold since the end of World War II. Fifty per cent more petroleum products by volume are being consumed in manufacturing plants. Lake shipping is converting increasingly to oil, as are most mines.

These trends, together with a further drop in the use of wood as a fuel, are likely to be modified by the arrival of natural gas from western Canada in 1958 or 1959. Retail sales of middle distillate oils for space heating purposes may slow down considerably. Coal may not only continue to lose out in respect to space heating but also be forced to give up a

Table 15

FUEL CONSUMPTION BY MAJOR USE IN ONTARIO, 1941, 1946 AND 1953

(thousands of tons of coal equivalent)

	1941					1946					1953				
	Coal	Oil	Gas[b]	Wood	Total	Coal	Oil	Gas[b]	Wood	Total	Coal	Oil	Gas[b]	Wood	Total
Manufacturing	4,385	798	383	100	5,666	4,641	899	399	47	5,986	6,325	1,497	679	101	8,602
Blast furnaces	850	—	—	—	850	913	—	—	—	913	2,136	—	—	—	2,136
Conversion uses[a]	510	481	90	—	1,081	570	714	103	—	1,387	505	802	147	—	1,454
Electric power	—	1	—	—	1	5	1	—	—	6	853	8	—	—	861
Shipping	359	65	—	—	424	346	84	—	—	430	359	246	—	—	605
Mining	105	29	7	28	169	120	11	26	13	170	116	83	2	—	201
Domestic and commercial	5,658	311	462	1,379	7,810	6,291	588	473	1,100	8,452	4,066	3,318	577	456	8,417
Railways	4,084	18	—	—	4,102	4,890	4	—	—	4,894	3,208	287	—	—	3,495
Total	15,951	1,703	942	1,507	20,103	17,776	2,301	1,001	1,160	22,238	17,568	6,241	1,405	557	25,771

[a]Principally the refining of petroleum products and the production of manufactured gas.
[b]Gas includes both manufactured and natural gas.

number of its manufacturing outlets as well. In the heavier types of industry residual oils sales will be less affected, natural gas being used in lieu of coal and on a seasonal basis.

Looking ahead to the mid 1960's it appears that coal requirements may fall by several million tons. Oil, with complete dieselization of the railways and further gains in manufacturing, may by then supply one-third or more of the province's total energy requirements. Natural gas, having established itself as a major competitor in the energy field, could be supplying close to 20% of Ontario's fuel needs a decade from now. In total, the Ontario market could increase from around 27 million tons of coal equivalent fuels in 1955 to better than 32 million tons ten years later.

After 1965 efficiency gains on a scale commensurate with those made in recent years appear less likely of achievement. Hence, Ontario's primary fuel requirements may move upward at an impressive rate. Meanwhile, the liquid fuels will become more solidly entrenched. By 1970 the part played by natural gas will be considerable; that by oil will have become relatively stable. Coal should have passed its nadir. After the mid-1960's imports from the United States will be augmented by a 7% or 8% per annum increase in thermal power generating capacity. Only to the extent that electricity can be produced by nuclear means is this latter requirement likely to be held in check.

Quebec

Quebec is the second largest fuel consuming province in Canada being exceeded only by Ontario. Currently some 15 million tons of coal equivalent fuels are being sold competitively there. Of this, about half is oil. In Ontario, by comparison, two-thirds of all the fuel consumed in non-highway uses still takes the form of coal.

Availability, and particularly price, has had a good deal to do with the shaping of these different supply patterns. Imported United States coal, moving across the lower lakes into Southern Ontario is cheaper by several dollars a ton than that delivered at Quebec City, Three Rivers and Montreal. On the other hand, oil and its products have been more readily available and more competitive in price in Quebec. This explains why the trend away from the solid fuels to oil has been proceeding more rapidly in the latter province.

Space heating and manufacturing are by far the largest fuel consuming categories. Together they account for close to three-quarters of all the energy (other than electric power and motor gasoline) used in Quebec. The railways still consume about twice as much as does shipping. Meanwhile, mining and thermal power requirements are comparatively modest, and that devoted to the production of manufactured gas on the decline.

Table 16

FUEL CONSUMPTION BY MAJOR USE IN QUEBEC, 1941, 1946 AND 1953

(thousands of tons of coal equivalent)

	1941					1946					1953				
	Coal	Oil	Gas[b]	Wood	Total	Coal	Oil	Gas[b]	Wood	Total	Coal	Oil	Gas[b]	Wood	Total
Manufacturing	2,646	539	13	142	3,340	2,279	495	15	117	2,906	2,747	1,471	29	70	4,317
Conversion uses[a]	71	360	—	—	431	117	395	—	—	512	112	595	—	—	707
Electric power	—	—	—	—	—	—	3	—	—	3	2	9	—	—	11
Shipping	—	270	—	—	270	—	329	—	—	329	—	820	—	—	820
Mining	88	16	—	28	132	112	33	—	9	154	102	74	—	6	182
Domestic and commercial	1,905	367	93	1,819	4,184	2,184	881	124	1,500	4,689	1,280	2,391	153	1,114	4,938
Railways	1,509	17	—	—	1,526	1,761	4	—	—	1,765	1,633	81	—	—	1,714
Total	6,219	1,569	106	1,989	9,883	6,453	2,140	139	1,626	10,358	5,876	5,441	182	1,190	12,689

[a]Principally the refining of petroleum and the manufacture of artificial gas.
[b]Gas includes manufactured gas.

Quebec energy requirements, while continuing to grow in an over-all sense, have been modified by the fuel efficiences resulting from the progressive substitution of oil for coal during the postwar period. While the province's paper mills, cement plants, metal smelters and refineries are still buying somewhat more coal than they did in 1946, both coal and wood have lost ground in the other market categories. Not only has oil supplied most of the growth requirements of industry but it has, over the past decade, made considerable headway in respect to space heating.

Consumption of Fuel in Quebec[a]
(millions of tons of coal equivalent)

Year	Coal	Oil	Gas[b]	Wood	Total
1941	6.3	1.6	—	2.0	9.9
1953	6.0	5.4	—	1.2	12.6
1965 est.	3.6	10.9	2.0	0.7	17.2

[a]Exclusive of highway use.
[b]Natural gas only.

Looking to the future, it appears that manufacturing, space heating and railway usage are likely to be the main determinants of demand. On the supply side, the arrival for the first time of natural gas must also be taken into account.

If the word dramatic appropriately describes the postwar turnaround in the Quebec space heating market, it may be an even more appropriate adjective to apply to the province's railways' needs between now and the early 1960's. The main line companies expect that their coal requirements will drop from better than 1.6 million tons in 1953 to only about 10% of that amount. Partially off-setting this will, of course, be a rise in railway oil consumption. Diesel fuel in an amount equivalent to some 500,000 tons of coal equivalent may be required for this purpose in 1965.

The prospects for coal in its other major outlets are less gloomy, if only by degree. Long-term trends in the sales of heating equipment and appliances, suggest that the continuing preference for liquid fuels will result in a further decline in coal sales equivalent to some 400,000 tons. Oil usage, meanwhile, may rise from around 2.4 million to around 4.0 million tons of coal equivalent in the early 1960's.

The main hope, in so far as coal is concerned, is manufacturing. While there may be a drop in the amounts of solid fuels used here, it may be of more modest proportions. The reasons are not altogether apparent. A number of processing industries are located well inland. Under these circumstances the present subventions paid on coal are rendering a switch to oil less appealing than if they were to be sited close to ocean shipping. Again, other manufacturing uses, such as in the aluminum plants and

non-ferrous metal smelters may rise, thus offsetting the tendency of cement plants, food processing establishments, etc., in and around the Montreal area to turn to oil and natural gas.

While the arrival of gas from western Canada will hurt coal, it will also have an impact on oil. This will be particularly true of the middle distillates sold largely for space heating purposes. Seasonal imports of the latter may, therefore, tend to level off if not actually be reduced. Meanwhile the heavier oils, and particularly those residual to Canadian refinery production will find a ready outlet in heavy industry down-river from Montreal.

In the two remaining fuel markets—gas manufacturing and mining—some coal will still be required. Artificial gas-making capacity in Montreal may be retained in use though essentially for peaking purposes. United States coal and some oil may be employed, quality and ease of handling being the main reasons for their choice. Meanwhile Quebec's metal and other industries may continue to use coal at about their present volume due largely to their location and to the existing freight rate structure.

In totalling up the demand for individual fuels in the mid-1960's we find that coal consumption may fall by between 2.0 million and 2.5 million tons. The railway conversion programme will be largely responsible for this. Oil meanwhile will come to dominate the energy situation in Quebec. Currently it is selling almost ton for ton with coal. By 1965, despite the marketing of some two million tons of coal equivalent natural gas in and around the Montreal area, petroleum products may out-sell coal in the ratio of around three to one. Thus within a decade oil may supply 60% or more of all the energy consumed in the Province of Quebec. Natural gas, meanwhile, will become the third most important fuel in this region. Outdistancing wood within a few years it may supply more than 10% of Quebec's non-highway needs a decade from now.

British Columbia

While British Columbia still consumes less fuel than the combined Prairie or Atlantic provinces it is one of the fastest, if not the fastest, growing markets for energy. Due mainly to the expansion of pulp and paper and metal processing operations, British Columbia's over-all requirements have risen by around 40% since the late 1930's. Though this rate of growth is in excess of that encountered in the central provinces, British Columbia now utilizes about one-fifth as much energy as Ontario and about one-third of that consumed in Quebec.

By far the largest use category in British Columbia is space heating. Alone it accounts for about 40% of all the coal, wood, natural gas and oil burned in the province. Manufacturing is in second place with close to 25% and the railways third with about 15%. In contrast to most other parts of Canada, ships' bunkering is still significant, amounting to around 10% in

recent years. Oil is well established. Today it supplies 60% of all the energy sold competitively throughout the province for non-highway purposes. Coal, which up until the early 1940's met about half of these needs, is now down to around 30%. Meanwhile, wood, still used extensively for space heating purposes, has fallen to around 15%. Natural gas, a comparative newcomer to the province, is only now beginning to be used on an appreciable scale.

Petroleum products, the extensive use of which began in British Columbia in the 1920's, have found their greatest acceptance in space heating, in manufacturing and on the railroads. For many years, residuals have been used by the pulp and paper mills and by the fish canneries up and down the west coast. Various grades of fuel oil have been used in increasing volume in the production of machinery, chemicals and in off-the-road logging and construction operations. Since 1946 they have also begun to be used fairly extensively in and around the mines and metallurgical centres of the interior as well.

Coal, meanwhile, has lost ground on all fronts. Substantially displaced on the railways prior to World War II, it has since been overshadowed in most uses except in the smelting and refining of base metals and in the manufacture of cement. Wood is also being used less and less as a fuel. This is partly due to the fact that wood wastes and pulp and paper mill residue are being incorporated to a greater extent in building boards and similar manufactured products.

Looking ahead to the early 1960's, oil will do well to hold its own in relative terms. While it will retain its market with many of the province's mining, chemicals and other primary processing industries, dieselization will cut the railways' demands by one-half. The arrival of natural gas will have narrowed the sales prospects of oil with respect to space heating, secondary manufacturing, and to thermal electric power stations. Natural gas, piped down across the province to the lower mainland from the Peace River District, besides being used by new industries en route, may also be employed in the manufacture of cement, other building products and even by oil refineries.

Such is likely to be the overwhelming importance of the liquid fuels that, together, oil and gas may, by 1965, be supplying between 80% and 90% of British Columbia's total fuel need. A decade from now coal sales may be less than one millon tons annually; those of fuelwood and wood wastes be down to about one-half of their present volume.

Contributing materially to the projected increase in demand is the fuel requirement associated with the generation of electricity from natural gas. Gas turbine and other internal combustion type plants will employ this fuel in any case. However, should available supply of hydro-electric energy in the lower mainland area threaten to be inadequate at any time,

Table 17

FUEL CONSUMPTION BY MAJOR USE IN BRITISH COLUMBIA, 1941, 1946, 1953

(thousands of tons of coal equivalent)

	1941					1946					1953				
	Coal	Oil	Gas[b]	Wood	Total	Coal	Oil	Gas[b]	Wood	Total	Coal	Oil	Gas[b]	Wood	Total
Manufacturing	311	194	9	38	552	354	307	20	26	707	531	568	7	32	1,138
Conversion uses[a]	32	68	48	—	148	24	117	7	—	148	16	183	31	—	230
Electric power	20	9	—	—	29	15	51	—	—	66	50	34	2	—	86
Shipping	91	356	—	—	447	85	458	—	—	543	6	446	—	—	452
Mining	123	29	—	7	159	103	15	—	7	125	97	41	1	5	144
Domestic and commercial	639	195	21	693	1,548	817	339	36	700	1,892	559	873	56	306	1,794
Railways	254	268	—	—	522	468	348	—	—	816	107	623	—	—	730
Total	1,470	1,119	78	738	3,405	1,866	1,635	63	733	4,297	1,366	2,768	97	343	4,574

[a]Principally the refining of petroleum and the manufacture of artificial gas.
[b]Gas includes manufactured gas.

substantial resort may have to be made to the burning of liquid fuels for this purpose.

The following tables illustrate the trends in inter-fuel competition which have been in evidence since the early 1940's and include provisional estimates for the mid-1960's.

Consumption of Fuel in British Columbia[a]
(millions of tons of coal equivalent)

Year	Coal	Oil	Gas[b]	Wood	Total
1941	1.5	1.1	0.1	0.7	3.4
1953	1.4	2.8	0.1	0.3	4.6
1965 est.	0.7	5.5	2.4	0.2	8.8

[a]Excluding highway use and hydro power.
[b]Including manufactured as well as natural gas.

The Prairie Provinces

Collectively the three Prairie provinces—Alberta, Saskatchewan and Manitoba—consume about the same amount of fuel as the Province of Quebec. Total usage of coal, natural gas and fuelwood thus is about half that of Ontario and about double that recently attained in the Province of British Columbia.

Per capita consumption is high. However, except for the amount of oil and gas utilized in the fields and in the gathering and main pipeline systems the rate of growth of demand in recent years has been well below the national average. The main reason for this has been the rapid decline in railway requirements as the conversion to oil progressed. Only recently have the fuel needs of the electric power utilities begun to loom large in the total. From now on they, together with manufacturing, may cause the Prairie consumption trend line to bend more persistently upward.[1]

Coal, as recently as 1953, was still "king" of the fuel market in this region. Nearly half of all the fuel requirements of the three Prairie provinces were being met from this source. The latest consumption statistics indicate, however, that it is approaching the end of an era. The situation there is very much in the state of flux. The era in which the solid fuels have dominated all other sources of supply is passing—and passing rapidly. With the conversion of steam burning rail locomotives to oil and, later, the complete dieselization of the railways; with further losses to both oil and gas in space heating and in manufacturing; and with certain of the newer central electric power stations preparing to burn natural gas. Coal is continuing to lose

[1]Space heating accounts for over 40% of all the energy consumed on the Prairies. Railways are still in second place with about 25% and manufacturing third with about 15%. Central electric stations, even now, consume less than 10% of all the fuel sold competitively in Alberta, Saskatchewan and Manitoba.

Table 18

FUEL CONSUMPTION BY MAJOR USE IN THE PRAIRIE PROVINCES, 1941, 1946 AND 1953.

(thousands of tons of coal equivalent)

	1941					1946					1953				
	Coal	Oil	Gas[b]	Wood	Total	Coal	Oil	Gas[b]	Wood	Total	Coal	Oil	Gas[b]	Wood	Total
Manufacturing	447	42	126	45	660	579	45	178	24	826	446	248	520	12	1,226
Electric Power	257	56	25	—	338	338	98	—	—	436	434	165	253	—	852
Mining	180	21	291	4	496	212	190	186	2	590	111	62	250	3	426
Domestic and commercial	2,186	67	922	1,339	4,514	3,040	142	1,245	1,100	5,527	2,095	983	1,418	406	4,902
Railways	2,677	144	—	—	2,821	3,283	271	—	—	3,554	2,541	791	—	—	3,332
All other[a]	49	244	5	—	298	23	274	5	—	302	2	772	2	—	776
Total	5,796	574	1,369	1,388	9,127	7,475	1,020	1,614	1,126	11,235	5,629	3,021	2,443	421	11,514

[a]Conversion uses principally *i.e.* oil refineries and manufactured gas plants.
[b]Including both natural and manufactured gas.

ground rapidly. Over-all consumption on the Prairies dropped by some two million tons over the past decade—the equivalent of a 25% to 30% drop since 1946.

Oil sales have more than tripled in this region during the post World War II period. Between 1946 and 1953, its contribution to the total energy supply rose from 10% to about 25%—a rate of increase that overshadows even that of natural gas. New space heating demands were most in evidence, although industry is already using up to five times as much oil as it did in the late 1940's. The railways, meanwhile, have about tripled their consumption of petroleum products.

The use of natural gas, which was already well established in the larger centres in Alberta ten years ago, has, more recently, spread to the cities of Saskatoon and Prince Albert in Saskatchewan. As a result, the largest single use category, residential and commercial sales, has been augmented considerably. Since 1950, the largest volume gains have been in primary manufacturing and, in central and northern Alberta, in the generation of electric power by thermal means. The larger amounts of gas being diverted into these low priced, large volume applications is a direct result of the improved reserve position in western Canada.

The record, in over-all terms, is somewhat surprising. Having risen by about 25% between 1941 and 1946, total fuel usage in the Prairie provinces has since tended to level off. It went up less than 10% between the end of World War II and 1953. In the face of an industrial boom this can only be explained on the grounds of greater efficiency in use. The rapid displacement of coal and wood by oil and gas—the liquid fuels being used in new and more efficient ways—has therefore masked what continues to be a substantial growth in the amounts of energy being put to effective use.

Such influences will continue to modify Prairie demand for fuel over the next decade. They have therefore been taken into account when attempting to assess the mid-term outlook by use sector through to 1965.

Fuel Consumption in the Prairie Provinces[a]

(millions of tons of coal equivalent)

Year	Coal	Oil	Gas[b]	Wood	Total
1941	5.8	0.6	1.4	1.4	9.2
1953	5.6	3.0	2.4	0.5	11.5
1965 est.	2.0	5.2	7.0	0.2	14.4

[a]Excluding highway use and the amounts used in the mining of coal and the production and pipeline transportation of oil and natural gas.
[b]Including natural gas liquids.

Within the total, two pronounced trends, one substantially offsetting the other, will be at work. The fuel requirements of the railways may be reduced by some two-thirds as a result of their projected oil conversion programme. Their annual coal purchases may therefore decline by two or more million tons. A persistent increase in electric power requirements, meanwhile, may result in a threefold to fourfold rise in the demand for fuels. From one million tons in 1963 this may be in excess of three million in 1965.

New industries, especially large fuel users like the pulp and paper industry, may also make a considerable difference in manufacturing. Along with more cement-making capacity, chemical plants, equipment manufacturing concerns and food processing applications these needs will doubtless put industry well ahead of the railways during the next decade.

The prospects, fuel by fuel, for the mid-1960's are as elsewhere in Canada; a further drop in coal sales, a continuing rise in the volume of petroleum products consumed, and a marked improvement in the position of natural gas. Our more detailed estimates indicate that coal may fall by more than 50%; oil will rise by about 70%; and the use of natural gas, as it spreads eastward across the Prairies, will nearly triple in the ten years immediately ahead. Meanwhile in the outlying areas the natural gas liquids will also be used much more extensively. Wood as a source of fuel energy will be largely displaced.

In the face of these developments, coal will retrench. Some will still be required in manufacturing and particularly in metallurgical operations. Much larger quantities will be needed for the generation of electricity. Here the low cost lignites and sub-bituminous coal deposits found close to the major consuming centres will be favoured. Strip mining operations tied closely to the electric power utility programmes can therefore be expected to grow. Many of the older underground mines both in the Prairies and in the more mountainous country to the west will, on the other hand, be closed down or be forced to operate at a fraction of their present capacity.

The Atlantic Region

Energy consumption in the Atlantic region— that is to say New Brunswick, Nova Scotia, Prince Edward Island, Newfoundland and Labrador—is presently in the order of 7.5 million short tons annually.[2] Having dipped sharply in the immediate postwar period it is now following a rising trend. Though the total equivalent tons of coal, oil and wood is only slightly higher today that it was in the early 1940's, the expectation is for a 15% to 20% rise in demand over the next decade.

Over-all statistics relating to the recent past are, to some extent, misleading. With the falling off of wartime shipping, total requirements dropped by nearly a million tons. A further though less significant down trend

[2]Exclusive of highway usage and hydro power generation.

Table 19

FUEL CONSUMPTION IN ATLANTIC PROVINCES, 1941, 1946, 1953

(thousands of tons of coal equivalent)

	1941					1946					1953				
	Coal	Oil	Gas[b]	Wood	Total	Coal	Oil	Gas[b]	Wood	Total	Coal	Oil	Gas[b]	Wood	Total
Manufacturing[a]	1,368	48	373	30	1,819	1,300	50	247	13	1,610	1,375	557	78	12	2,022
Conversion uses[c]	105	110	—	—	215	92	95	—	—	187	105	108	—	—	213
Electric power	274	3	—	—	277	348	7	—	—	355	540	32	—	—	572
Shipping	634	996	—	—	1,630	273	492	—	—	765	82	482	—	—	564
Mining	420	2	4	1	427	308	4	4	—	316	264	21	5	2	292
Domestic and commercial	1,126	104	27	722	1,979	1,252	193	24	640	2,109	1,563	719	6	563	2,851
Railways	989	2	—	—	991	1,098	3	—	—	1,101	762	104	—	—	866
Total	4,916	1,265	404	753	7,338	4,671	844	275	653	6,443	4,691	2,023	89	577	7,380

[a] Includes blast furnace coke.
[b] Includes manufactured gas.
[c] Principally the refining of petroleum and the manufacture of artificial gas.

has been more than offset by increased demands from other sectors, particularly those related to resource development.

The greatest strength from now on is in connection with electric power, although the fuel needs of the region's pulp and paper mills, food processing plants and other manufacturing and residential and commercial users have all been edging steadily upward. Opposing this is rail dieselization. Its resultant economies are only now beginning to be effective. From now on, declining railway requirements will continue to moderate what otherwise would be a more impressive upsurge in energy consumption generally.

Inter-fuel competition, at the same time, is increasing. Up until the late 1940's the region's coal mines encountered little difficulty in selling most of their output. Even after 1950, the stimulus given to economic activity by the Korean emergency helped to mask the inroads which oil was beginning to make into its markets. Now, however, competition from the liquid fuels is becoming more intense. Not only has a world petroleum surplus made oil a more formidable adversary but the modernization and expansion of refining facilities within the region itself is also helping to balance and to strengthen the position of the middle distillates in what were formerly many of coal's more lucrative outlets.

Oil usage which experienced a temporary setback with the declining shipping activity which characterized the immediate postwar years, has since come back strongly in most of the high price use categories, including space heating, secondary manufacturing and railway transportation. Residual oil is also making a strong bid for markets in most of the bulk fuel using industries, such as pulp and paper, mining and in the generation of electric power where price per B.t.u. is all important.

Liquid fuel sales, as a result, have risen two and one-half times since 1946. Coal, on the other hand, has been barely holding its own. Indeed, it has lost customers on every front except that of power production. Fuelwood is even more seriously effected. These trends, together with the projections to the mid-1960's are reflected in the following table.

***Fuel Consumption in the Atlantic Provinces*[a]**
(millions of tons of coal equivalent)

Year	Coal	Oil	Gas[b]	Wood	Total
1941	4.9	1.3	0.4	0.7	7.3
1953	4.7	2.0	0.1	0.6	7.4
1965 est.	4.5	4.7	0.1	0.4	9.7

[a]Exclusive of highway use.
[b]Manufactured and natural gas.

Should the above forecast be validated by events, coal will fall below oil sometime around 1965. Wood—the other solid fuel—may fall from around

9% to something like 5% of total demand. By contrast, the liquid fuels may rise from something like 30% at present to a position where they will be supplying about half of the Atlantic region's total energy requirements ten years from now.

Nor does this appear to be a passing phase. The area's dependence upon imported fuels over the long run is much more likely to increase than to decline for many years. Most, if not all, of its growth requirements will probably be supplied directly from Canadian refineries or by imports of products from abroad. Natural gas cannot be ruled out. Should it eventually prove possible to liquefy the natural product and transport it by tanker to, say the United Kingdom, gas distribution in eastern Canada may be similarly affected. Propane and the other natural gas liquids—all by-products of natural gas production—will also be available. Vying more with the lighter fractions produced from crude oil they, too, will make it more difficult for coal to recapture such markets as space heating, the heat treatment of metals and the manufacture of certain building materials where quality and ease of control are also likely to influence the user's choice.

Looking even further ahead there is the prospect of nuclear energy. Since the Atlantic region comprises a high cost energy area it might be one of the first outside of Southern Ontario in which atomic power plants prove to be economic.

Average Fuel Costs[a], by Province 1953

(cents per million B.t.u.'s)

	Coal	Fuel oil	Natural gas	All fuels
Newfoundland	.86	.47	—	.51
Prince Edward Island	.57	.96	—	.87
Nova Scotia	.35	.48	—	.46
New Brunswick	.42	.57	.55	.47
Quebec	.45	.54	.67	.54
Ontario	.37	.64	.79	.49
Manitoba	.22	.44	.15	.39
Saskatchewan	.43	.38	.15	.49
Alberta	.18	.49	.15	.25
British Columbia	.37	.53	.85	.54
Yukon	—	.28	.37	.34

[a]Fuel consumed by the manufacturing industries.

Defence considerations will, at the same time, militate against undue dependence of the electric power producing utilities upon imported liquid fuels. On the other hand, an attempt to produce most, if not all, of the region's electricity requirements from coal would probably result in an excessive increase in power costs. Nuclear energy—depending upon the

flexibility and optimum size of future atomic power plants—may therefore serve to lessen the demands for fossil fuel, be it coal or oil, which would otherwise stem from the region's growing requirements for electricity in the 1970's and 1980's.

Regional fuel prices have been discussed in Chapter 2 where the relationship between fuel costs and the volume consumed was examined. The following table which shows the average fuel costs in the manufacturing industries, by province, is also interesting. The table serves in some measure to illustrate the regional problems of fuel transportation and of fuel supply.

13

NATIONAL SUPPLY-DEMAND TRENDS, 1955-80

Section I: Introduction

Entering the second half of the 20th century, Canada is consuming energy at a rate of approximately 100 million tons of coal equivalent a year. Per capita utilization, which is now in the order of seven tons, exceeds that of all other countries except the United States. The latter's per person requirements are now slightly in excess of eight tons a year. Since the beginning of the 20th century, per capita requirements in this country have roughly doubled; total supply, which also takes into account population increases, has risen around fivefold.

Meanwhile, energy is being used more productively. The average efficiency with which the various fuels and water power are being put to work is at least double that of 1900. This means that, while the average Canadian burns up or otherwise employs twice as much energy as did his predecessors 50 years ago, he obtains four times as much benefit from it. Similarly, while the total quantity of primary energy consumed has grown five times, that put to effective use has increased tenfold.

Remarkable changes have also taken place on the supply side. The solid fuels have diminished in importance. The liquid fuels, and particularly water power, have increased many times over. These trends may all be projected into the future. However, a statistical exercise of this kind frequently results in inconsistencies. Judgment must be employed in circumstances where entirely new conditions are being encountered. It is with a view to combining the best features of the statistical and qualitative approaches that the present chapter has been written.

In what follows, various methods for determining the 20-year to 30-year outlook have been employed. Yielding different results, they have subsequently been averaged out. In the interests of clarity, a single figure has frequently been employed. The reader is urged to recall, however, that these forward looking statistics are employed merely as indicators of change. Fully

documented, they would appear instead as a range of estimates—estimates which could be explained only in the general context from which they have been developed.

There follows in sequence:

1. a statistical projection of past energy requirements through to 1980;
2. a forecast of future energy requirements based on future expectations as to G.N.P. and past relationships between G.N.P. and energy inputs;
3. a forecast of future energy requirements based on future expectations as to the nation's labour force and past relationships between the working force and energy consumption in this country;
4. an analysis by major end-use, advantage being taken of the projections of growth as reported in other industry studies prepared under the auspices of this Commission; and
5. mid-term (1965) energy requirements as obtained by totalling up the regional forecasts.

Finally, these demand estimates are compared with those arrived at and reported in Part B, dealing with the individual energy commodities, *i.e.* coal, oil, natural gas, water power, etc. Thus, judgments as to the changing supply pattern are reconciled with the total demand for energy as obtained by the various methods outlined above.

Section II: Estimates of Demand

Projection of Gross Energy Supply

The past record of growth of the energy supply can be divided into several time periods. During the first 25 years of this century, the gross supply of all types of fuel and power (when reduced to some such common denominator as B.t.u.'s) showed an annual rate of increase of between 3% and 4%. By contrast, in the decade after 1929, total Canadian requirements underwent little change. Following World War II or during the past decade, the energy supply has been increasing at an average annual rate of slightly more than 4% compounded.

In looking ahead, several base periods might therefore be chosen. Each, depending on whether they included the depression years or not, would yield different results. That covering the 20 years from 1935 to 1955 would suggest a 4.5% yearly rate. Alternatively, a 30-year span starting with 1926, would suggest that a 3% per annum increment be employed.

In order to be consistent with our basic assumptions as to full employment and no all-out war, a narrower band of possibilities was chosen. A lower limit of 3.5%, when applied to present energy requirements, indicated a total national demand in 1980 in the order of 260 million tons of coal

equivalent energy. Using 4%, we arrive at 290 million tons. The aggregate forecast of Canadian energy requirements, using this statistical method, therefore, is for close to a threefold multiplication of demand over the next quarter century.

Projection of the Energy Demand-G.N.P. Relationship

It is possible, using the statistical technique of correlation analysis to allow for expected developments in the economy as a whole. The result is a theoretical level of consumption which, while it fits closely past experience, also allows for a marked acceleration in economic development generally. It is an interesting fact that energy requirements in this country have lagged progresssively behind G.N.P. Further changes in this relationship, together with the Commission's expectations with regard to both population and worker productivity, are therefore taken into account when using this approach.

From an inspection of a scatter diagram showing the relationship between energy consumption and G.N.P., it is apparent that the two series are intimately related. (See chart, Canada: 1980 Energy Forecast.) The correlation coefficient obtained for the data plotted was .99, which means that 98% of the changes experienced in this country's gross energy supply can be explained by the estimating equation:

$$\text{Energy } (10^{12} \text{ B.t.u.'s}) = 310.54 + .20093 \text{ (G.N.P. in millions of 1935-39\$)}.$$

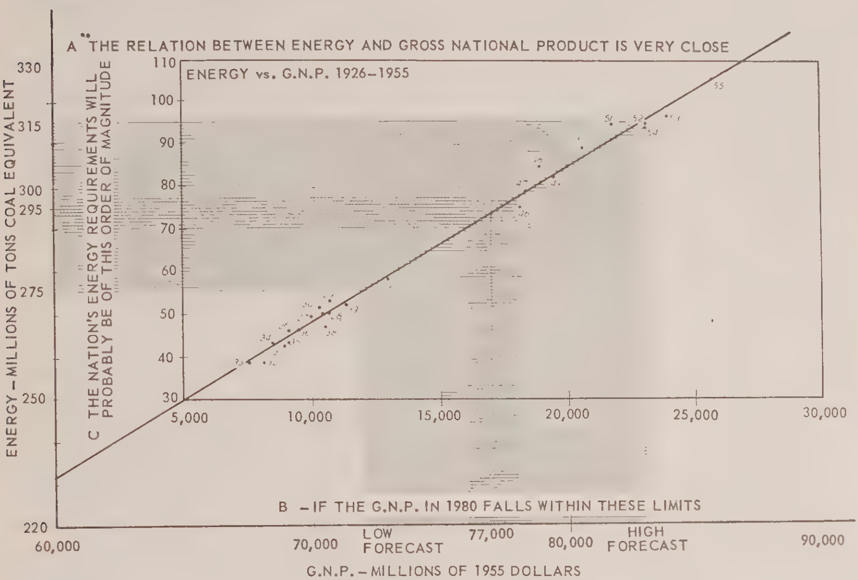
In view of the high correlation obtained, the regression equation offers a reliable method for estimating the volume of energy which will be consumed for a given G.N.P. Based on data for the years 1926-54 (but omitting the years 1941-45), it has, been employed by us to obtain a forecast for the year 1980.

Future expectations as to G.N.P. were obtained from the other Commission studies. These (in 1955 dollars) are for a high of $83 billion; a low of $71 billion; and a middle forecast of $77 billion in 1980. Introduced into the above equation, they yielded gross energy requirement forecasts of 310 million, 265 million and 285 million tons of coal equivalent annually, 25 years from now.

In the past, energy requirements per units of G.N.P. have declined. If the average of the years 1926 to 1930 were taken as 100, raw energy inputs over the interval 1936 to 1940 would be approximately 94; 1946 to 1950, 87; and 1951 to 1955, 83. Continuing efficiency gains in this order of magnitude would imply an index in the order of 70 for the average five-year period centring on 1980. This, together with a nearly threefold multiplication of G.N.P. would result in a total demand for energy in the order of 270 million tons. As stated elsewhere (see Appendix D), the scope for further improvements in efficiency is not as great as that which has

existed over the past two or three decades. In other words, an index of 75 or even 80 might reasonably be chosen as applicable to the 1960's and 1970's. Their use in turn would result in a total Canadian requirement in 1980 in the order of 285 or 300 million tons of coal equivalent a year.

CANADA: 1980 ENERGY FORECAST



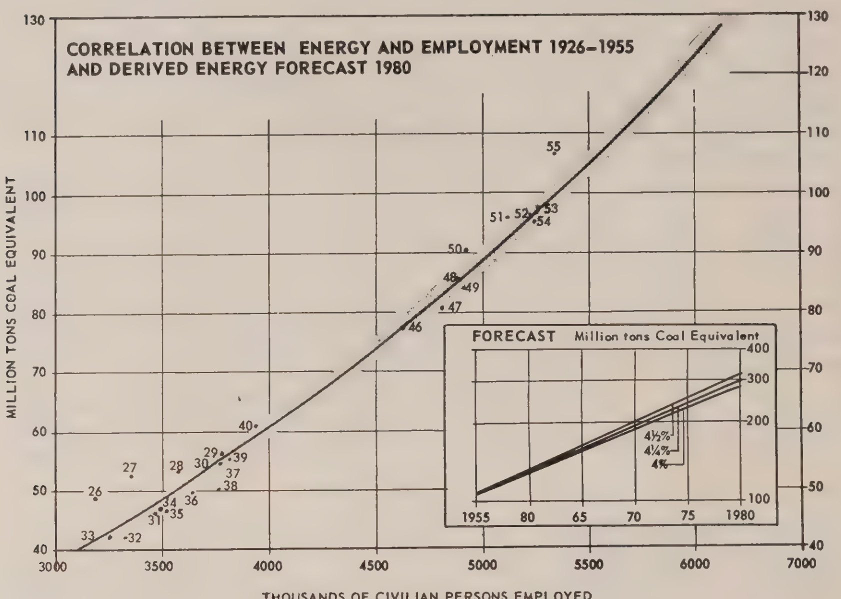
Projection as Related to the Nation's Labour Force

The use of energy per person in Canada has moved upward in irregular fashion since the turn of the century. It rose sharply between 1900 and 1910. Thereafter, it remained virtually constant around five tons until the outbreak of World War II. Since 1939, however, a further 40% rise in the amount of energy used per person has occurred. Usage per capita, in other words, grew rapidly at the beginning and towards the end of this period. Yet there was an interval of 30 years (between 1910 and 1939) in which the nation's total energy requirements and population moved more or less in step with each other.

Because energy requirements are affected much more by economic conditions, there is a closer relationship between the energy supply and the working force than between the energy supply and population. The former was, therefore, chosen as the basis for projecting future needs. As in the case with G.N.P., the base period chosen was 1926 through to 1955 but omitting the war years. The historical relationship, which showed a degree of correlation of .95, is portrayed in the equation:

log. Energy (10^{12} B.t.u.'s) $= -3.39539 + 1.83205$ log. (Civilians employed in thousands of persons).

For the future, the only variable was taken to be the working force. Assuming it rises from five million at the end of 1955 to nine million in 1980, energy requirements in that year would be in the order of 260 million tons of coal equivalent. A 9.5 million labour force would result in a 290 million ton coal equivalent demand; a 10 million employment figure, a 315 million ton coal equivalent requirement 25 years from now. (See chart: Correlation Between Energy and Employment.)



Forecast of Demand by Principal End-Use

Another approach, which is at the same time more descriptive of likely developments internal to the Canadian economy, can also be used in assessing future Canadian requirements. Individual projections relating to such major use categories as space heating, highway use and manufacturing can subsequently be added up to obtain a total figure for Canada in 1980. In following this procedure, greater attention must necessarily be paid to the nation's export prospects, to the varying rates of growth of different industries and the increasing consumer preference for energy in its more highly manufactured forms. At the same time, past and future relationships between the different forms of energy are brought into somewhat better focus. The results, when spelled out in terms of the different energy sources, in so far as coal, oil, natural gas and water power are concerned, have then been employed as a check on the separate commodity projections as reported in Chapter 4.

Some idea of the relative importance of the individual energy use categories can be obtained from the following table:

Energy Consumption by End-Use, Canada, 1953

End-use category	Volume consumed 10^{12} B.t.u.'s	000 tons coal equivalent	Percentage of total energy supply
Residential and commercial	780	29,000	30.0
Transportation	775	28,500	29.5
Manufacturing and mining	600	22,200	23.0
Non-fuel uses	140	5,200	5.5
Energy industries:			
Production	15	500	0.5
Processing	200	7,400	8.0
Waste, unaccounted for, etc.	100	3,700	3.5
Total supply	2,610	96,500	100.0

Residential and commercial usage and transportation appear to be the two most important categories. Each presently accounts for about 30% of total Canadian energy requirements. Industry in the somewhat restricted sense of manufacturing and mining, meanwhile, employs about 23%. Another 9% is used up in energy production and in the conversion of crude oil to refined products, coal to coke and gas and the various fuels to thermal power. Non-fuel uses, including chemical and metallurgical applications, presently account for about 5%. All industry, exclusive of transportation and the residential and commercial categories of use, consequently, absorbs 35% or more of the nation's energy supply.

Residential-commercial requirements

At present, households and commercial establishments consume close to 30% of the nation's total energy supply. By far the largest application is space heating. For this reason, fuels provide nine-tenths of all the energy utilized in the nation's homes, stores and other commercial establishments.

However the Canadian climate is less of a penalty than it used to be, for the provision of comfort heat has been declining in relative importance. This is illustrated by the decline in residential-commercial energy requirements relative to total national energy requirements. Expressed as a percentage of the gross energy supply it has fallen from around 40% in the interwar period to around 28% at the present time. Meanwhile electricity has gained relative to the fuels, from negligible proportions in 1925 to the point where it now supplies about 10% of all energy consumed for residential and commercial purposes.

In per capita terms, the fuel input side has remained relatively stable. The amount of fuelwood, coal, oil and natural gas consumed per person has varied little from the mid-1920's to the present. Such demand aug-

mented influences as fewer persons per household, more rooms heated continuously and higher average room temperatures have apparently been offset by improved building design, better insulation, more efficient fuel burning units and the widespread use of automatic controls. Statistically, we have, therefore, good reason to anchor our future projections of fuel requirements to population. Since the latter is expected to rise by approximately 70%, the aggregate fuel needs of the residential-commercial sector have, therefore, been assumed to rise by a comparable amount over the next quarter century.

Meanwhile, electric power will be used more extensively. The long-term upward trend (as described in Chapter 9) is of the order of 8% per annum. This is approximately four times the 2% yearly rate assumed to apply to total fuel needs.

Total Canadian residential-commercial requirements currently are in the order of 30 million tons of coal equivalent annually. Allowing for divergent rates of growth between the fuels and power, we arrive at an over-all requirement in the vicinity of 60 million tons in 1980. Of this, approximately 20% will take the form of electricity.

As to fuel supply, natural gas is expected to show the greatest gain while coal and wood consumption may decline both relatively and absolutely.

Residential and Commercial Fuel Requirements
(percentage of total consumption)

	1926	1939	1948	1953	1955	1965	1980
Wood[a]	34	33	28	21	18	13	5
Coal[b]	64	58	52	37	29	18	7
Oil[c]	—	5	14	33	43	50	48
Natural Gas[d]	2	4	6	9	10	19	40
Total Fuel	100	100	100	100	100	100	100

[a]Including sawdust and other wood wastes.
[b]Including coke.
[c]Including oil refinery produced L.P.G.'s.
[d]Including natural gas liquids.

Transportation requirements

Energy consumed in the transport sector is herein assumed to include the requirements of the railroads, ships, aircraft, highway, and off-the-road vehicles. Allowances have also been made for oil and gas pipeline and electric power transmission and distribution losses.

For many years between 25% and 30% of the nation's gross energy supply has been devoted to the purpose of moving people and goods from one place to another. Meanwhile the modes of transportation themselves have changed considerably. So have the engines and the types of fuel and power devoted to this purpose. The automotive sector has increased tremendously; that of the railways declined. Shipping has no more than held

its own, while pipeline transportation in Canada is a development of the past decade.

These trends, together with the more extensive use of the automobile for non-commercial purposes, have favoured oil. Gasoline consumption alone has grown from around 4% of the nation's total energy purchases in 1926 to approximately 15% in 1955. The amount of coal burned in railway locomotives, meanwhile, has dropped from 20% to around 5% in the same period.

Not only is this sector complex, in that the various modes of transportation and supply are changing, but efficiency in use varies considerably from one application to the next. It is also changing with time. For these several reasons it has been necessary to deal with each of the major uses separately, relying where possible upon other staff studies for forecasts of the future level of activity in the various individual transportation fields.

Automotive requirements (and this includes the fuel needs of all automobiles, trucks, tractors, and other similar mobile motor-driven equipment) may increase threefold during the next quarter century. That involved in driving automobiles may increase most; farm tractors and similar construction equipment least. Trucks and other commercial vehicles may occupy a position somewhere between the two.

There is considerable scope for efficiency gains in this area. The more extensive use of diesel power in commercial and off-the-road vehicles and equipment will have a moderating influence on demand. So would a stabilization of the horsepower ratings of the average automobile engine. It is largely on these grounds that a level of automotive needs in 1980 approximately three times that reported in 1955 is estimated.

In view of the numerous possibilities on the technological front a further cautionary note should be struck. Improved carburetion and higher compression ratios can result in greater fuel economies than those envisaged here. A reduction in idling time and a better matching of engine to continous traffic requirements can have an even greater effect in this direction. Gas turbines, on the other hand, may be more wasteful of fuel. To the extent that they are introduced in smaller vehicles they will tend to offset the higher energy economies which can be obtained through the more extensive use of diesel and other reciprocating engines.

Efficiency considerations are paramount in any consideration of future railway requirements. With the gradual disappearance of the coal burning steam locomotive—Canadian railways will be almost completely dieselized by 1961—fuel purchases have declined sharply. During 1954 locomotives consumed the equivalent of 8.5 million tons of coal, of which the equivalent of 800,000 tons of coal was diesel oil. Yet diesel locomotives in that year performed—using less than 10% of all locomotive fuel—45% of all freight hauling; 55% of all switching and 15% of all passenger hauling.

Once the change to diesel locomotives has been completed the fuel requirements will move more in line with the level of railroad activity. The transportation study projects the latter as rising over the long-term at a 2% per annum rate. This, together with an adjustment for the railway's non-locomotive fuel uses, results in an energy requirement 25 years hence of about half that reported for 1955.

Of this four million tons (coal equivalent) of fuel required in 1980, the great bulk will be oil. Some coal may however be employed in gas turbine locomotives employed on long hauls in eastern Canada. Natural gas liquids may also lend themselves to gas turbine use in Alberta and British Columbia. On the other hand, nuclear powered locomotives were not assumed to have reached a stage of development sufficient to allow their use on an appreciable scale a quarter century from now.

Canada's shipping now makes use of about 3% of the nation's gross requirements. Two-thirds or more of this is oil. In this study it has been assumed that, with revenues increasing to between three and four times their present level, marine energy requirements might approximately double. Oil was assumed to take over approximately 90% of this market; nuclear energy and coal both 5%.

The greatest relative growth will undoubtedly take place in aviation. Air traffic volume, both freight and passenger, may multiply six times or more by 1980. There is, at the same time, less latitude for fuel savings to be effected in this field. The gas turbine engine and particularly the turbo-jet offers few direct economies over its piston equipped counterpart. Appreciable gains may however be made in marrying engines to aircraft and in designing air frames to fit more closely the requirements of particular types of services. With these savings in mind, a provisional fivefold increase in aviation fuel requirements has been forecast. The bulk of this will probably be turbo-fuel rather than gasoline although both will have to be produced from crude oil.

The following tables are designed both to show the changing relative importance of these different transportation fuel markets and to illustrate how these growing needs may be met.

Transportation Energy Requirements by Type of Use
(percentage of total consumption)

Use category	1926	1939	1948	1953	1965	1980
Automotive	14	31	34	48	66	63
Railway	80	53	54	39	15	8
Marine	6	13	9.0	8.7	9	8
Airline	—	0.2	0.6	1.0	3	8
Pipe and power lines	—	2.8	2.4	3.3	7	13
All transport	100	100	100	100	100	100
Total in million tons of coal equivalent	11.5	14.3	24.0	28.6	42.0	72.0

Energy Used in Transportation by Source
(percentage of total consumption)

	1926	1939	1948	1955	1965	1980
Coal	74	54	54	27	2	3
Oil	25	43	43	70	93	86
Gas[a]	—	—	—	—	2	5
Electricity	1	3	3	3	3	6
Total	100	100	100	100	100	100

[a]Including natural gas liquids.

Manufacturing and mining

Industrial requirements in the manufacturing[1] and mining sectors have, collectively, been mounting more rapidly than those of any other major use category. Amounting to some 17% of the nation's total energy supply in 1926, they are now equivalent to about 23%. A measure of the absolute growth is given by the following table. It shows manufacturing and mining requirements multiplying approximately threefold while total Canadian energy usage rose only a little more than twice over the past 30 years.

Energy for Industry vs. Total Energy
(index: 1926 = 100)

Year	Industrial energy	Total energy
1926	100	100
1929	116	114
1933	85	82
1939	130	116
1944	223	157
1948	241	182
1953	287	215

While industry has been using more fuel and power, it has also been employing these purchases more productively. Manufacturing and mining output, as measured in real dollar value, has, in other words, been rising at least as fast as, if not faster than, the energy intake of most manufacturing plants and mining concerns. This is confirmed by the more detailed information which is available for the years 1935 onward. Over the past two decades, the average annual rate of growth of energy consumption in manufacturing has been of the order of 5%. Meanwhile, both manufacturing and mining activity has followed a more prononunced upward curve. Since the mid-1930's, it has for manufacturing more nearly approximated 6% com-

[1]Excluding such manufacturing industries as are engaged in the conversion of energy from one form to another, *e.g.* the refining of oil, the production of artificial gas and coke and the generation of electric power.

pounded. Over the short term, much wider fluctuations have occurred. These can be illustrated as follows.

Energy per Unit of Manufacturing Production
(index: 1929 = 100)

1929	1933	1939	1944	1948	1953
100	97.5	102	89	115	96

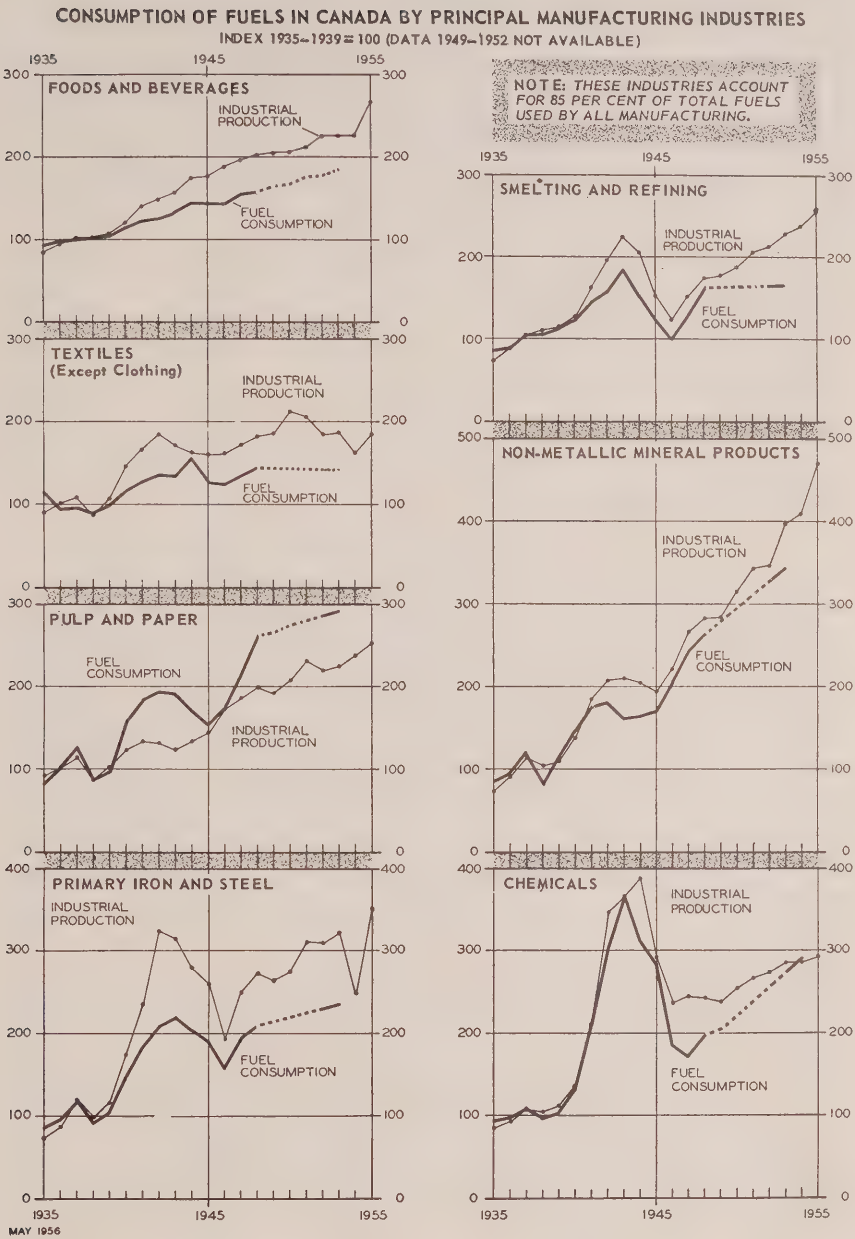
Various reasons can be ascribed to these fluctuations. One is the increased efficiency with which energy, particularly the liquid fuels, is being put to work. Another is a continuing change in industrial structure. The primary processing, export oriented industries are relatively less important now then they were in the interwar period. Being less energy intensive, a relatively higher rate of growth in secondary manufacturing has therefore helped to moderate what otherwise would have resulted in a greater relative demand for both fuel and power.

In attempting to look ahead 20 or 30 years, two different methods of projection can be applied. One involves an over-all judgment of the prospective rate of industrial growth. The other approach is to look at mining and each of the other major industrial manufacturing categories separately. Both, modified to the extent of expected efficiency improvements, will give an approximate order of the demand for energy in Canadian industry in 1980.

The calculations appearing in the table Estimated Energy Requirements of Canadian Industry in 1980 make some allowance for changes in Canada's industrial structure. Input-output judgments, as they apply to the future, have been derived from the more detailed statistical analysis represented graphically. (See chart: Consumption of Fuels in Canada by Principal Manufacturing Industries.) This method points to a threefold increase in requirements over the next quarter century.

As a check, the past correlation between energy purchases and industrial output was projected ahead for 25 years. This indicates that a 4.5% annual growth rate in industry might result in a 4.3% increase in energy requirements. Since such efficiency gains as have been accomplished over the past two or three decades are not as likely to be attained in the future, a parallel or 4.5% growth rate with respect to these fuel and power needs has been selected. In other words, total requirements in this sector may multiply approximately three times between now and 1980. That is to say, they may increase from approximately 23 million tons of coal equivalent to 70-75 million tons 25 years from now.

Now as to supply: industry is presently demanding between one-fifth and one-quarter of its energy in the form of electricity. Over the long run, this proportion appears to be rising; the direct contribution of the fuels,


CONSUMPTION OF FUELS IN CANADA BY PRINCIPAL MANUFACTURING INDUSTRIES
INDEX 1935–1939 = 100 (DATA 1949–1952 NOT AVAILABLE)
NOTE: THESE INDUSTRIES ACCOUNT FOR 85 PER CENT OF TOTAL FUELS USED BY ALL MANUFACTURING.
FOODS AND BEVERAGES
TEXTILES (Except Clothing)
PULP AND PAPER
PRIMARY IRON AND STEEL
SMELTING AND REFINING
NON-METALLIC MINERAL PRODUCTS
CHEMICALS
INDUSTRIAL PRODUCTION
FUEL CONSUMPTION
1935
1945
1955
MAY 1956

declining. This tendency, together with the progressive shift from coal to oil and gas, is recorded statistically in the following table. The forecasts for 1980 were made after examining closely similar data for the United States and particularly those areas where the liquid fuels have, for some time, been available in quantity and offered at prices fully competitive with the medium and higher grades of coal.

Energy Consumption of Industry in Canada 1926-80

(percentage of total)

	1926	1939	1955	1980
Coal[a]	68	58	46	15
Oil	6	9	22	30
Gas[b]	4	6	7	25
Wood	7	2	1	—
Electricity	15	25	24	30

[a]Including coke.
[b]Including natural gas liquids.

Non-fuel uses

The amount of coal, oil, and natural gas consumed for non-fuel purposes in 1955 was in the order of six million tons. It, therefore, amounted to 5% of total energy consumption. Slightly more than half of this, or more than three million tons, consisted of metallurgical coke. This was consumed largely in the production of primary iron and steel, although smaller amounts are also employed in the smelting of other metals. Between 15% and 20% consisted of petroleum and natural gas liquids and natural gas feedstock, essentially in the production of organic chemicals. The remainder included such commodities as pitches, tars, and asphalts used in construction and such other crude oil products as lubricants, waxes, and petroleum coke.

According to the Commission's other staff studies, there is considerable scope for expansion in the majority, if not all, of these sectors. Metallurgical coke requirements may be about three times their 1955 level in 1980. Construction expenditures and, hence, the demand for petroleum based building and paving materials may rise in similar fashion. Industrial chemical production may show a sixfold increase; petrochemical material requirements may rise even faster. The demand for petroleum coke, since it is essential to the electro-process industries, will also be required in substantially greater amounts.

Summing up these somewhat divergent trends, we find that the total requirements in 1980 may be about four times its present tonnage. Amounting in 1980 to between 20 million and 25 million tons, it may represent 7% or 8% of the nation's total needs 25 years from now.

Because of the growing importance of petrochemical production, oil and especially natural gas and the natural gas liquids, may share increasingly in this non-fuel market. Whereas coal in the form of coke presently supplies about 55% of the total, it may be down to about 45% in a quarter century. Crude oil and its products, meanwhile, may remain at about 40% while natural gas and its lighter by-products may contribute something like 15% as opposed to less than 5% of the total supply made available for this purpose in 1955.

(percentage supplied by type of fuel)

Year	Coal[a]	Oil	Natural gas[b]
1955	55	40	5
1980	45	40	15

[a]As coke.
[b]Including natural gas liquids.

Energy production and conversion

A substantial amount of energy is used up or otherwise lost in the initial production of coal, oil and natural gas. More coal is being converted either to coke or to electricity and the products of crude oil are becoming more highly manufactured. All this calls for a greater input of energy. However, greater consumption in the energy producing sector has, meanwhile, been reducing the amounts required at subsequent stages in the economy, particularly in transportation and in manufacturing.

At the present time, about 10% of the nation's total energy supply is used to produce and process fuel and electricity. This proportion is bound to increase. It will rise as Canada moves from the position of a net importer to that of a net exporter of oil and natural gas. Production requirements, in other words, will grow along with this country's increasing status as a source of liquid fuels. Energy processing—now much more important—may also gather in momentum. Until recently, confined largely to the refining of oil and the manufacture of coke and artificial gas, it will soon receive considerable impetus from the thermal generation of electricity based on coal, oil, and natural gas.

The extent to which primary energy has been processed or otherwise converted to other forms has changed materially since the mid-1920's. In 1926, the ratio between that used in the natural state and that which had received some degree of processing was of the order of 4:1. Now, it is about 1:1. About half of the the energy needs of the economy, external to the energy producing sector are met through the use of coke, manufactured gas, refined petroleum production, and electricity manufactured from the fossil fuels.

The quantity of energy used up in this way has risen in parallel fashion. Only 5% of the total energy supply was used up in the conversion process in 1926. Presently about 10% is so employed. It is reasonable to expect that these happenings will speed up rather than slow down. So far, this sector of the Canadian economy has been physically very efficient. Coke and gas plant internal consumption and losses rarely exceed 15% of the raw fuel consumed. Only about 10% of the oil purchased by the refineries is utilized by the refineries themselves. Thermal power generation, on the other hand, involves losses of a different magnitude. The average over-all efficiency of the steam electric plant in this country is currently in the order of 20%. Even if this figure should rise to between 30% and 35% in the late 1970's, it can be seen that the generation of electricity by thermal means will result in a substantial increase in non-productive requirements.

The amount of energy consumed in the primary production of fuels in 1980 will, of course, be related to the volume of fuel production. Including the crude oil and natural gas destined for export, the total production of liquid fuels and coal is expected to be in the order of 400 million tons of coal equivalent or eight to nine times the current level of output. The energy required to produce this volume of coal, crude oil and natural gas, however, will increase only about six times from the current level of about 500,000 tons coal equivalent to about three million tons. Coal mining, which requires larger expenditures of energy than either crude oil or natural gas production (on a comparable basis), will become a smaller part of total fuel production as the years pass.

The energy processing industries will grow more in line with the growth of the economy and, hence, their energy requirements and the losses associated with processing, will increase accordingly. Only in the field of electric power is this not true. Here, despite the continuing expected improvement in thermal station efficiencies from just over 20% at present to about 35% by 1980, over-all losses will increase greatly because thermal generated electricity is growing as a percentage of all electricity.

In the major energy processing industries, coke-making is expected to triple; oil refining to increase three and one-half times; while the losses associated with thermal power production increase from five to six times. In terms of coal equivalent, the total fuel requirement including losses will increase just over four times, to about 34 million tons.

Having arrived at an estimate of the level of energy demand in each of the major end-use sectors, we now combine these estimates to obtain the total energy demand for the economy.

Forecast of Demand by Region

The nation's mid-term fuel requirements have previously been discussed, region by region, in Chapter 5. Included were projections ahead

Energy Demand by Major Use 1953 and 1980
(millions of tons coal equivalent)

Demand sector	1953 Volume	1953 Percentage	1980 Volume	1980 Percentage
Residential and commercial	29.0	30	60	21
Transportation	28.5	29	72	26
Manufacturing and mining	22.2	23	80	29
Non-fuel uses	5.2	5	23	8
Energy industries				
Production	0.5	9	5	14
Processing	7.4		34	
Waste, unaccounted for	3.7	4	6	2
Total	96.5	100	280	100

to 1965. Totalled up along with forecast demands for motor gasoline and water power, they point toward a 3.5% per annum increase in the demand for all types of energy over the next decade:

(millions of tons coal equivalent)

Region	1953	1965	Rate of increase
Ontario	25.8	32.5	2 %
Quebec	12.7	17.2	2.5 %
British Columbia	4.6	8.8	5 %
Prairies	11.5	14.4	2 %
Atlantic	7.4	9.7	2.25%
Total fuel	62.0	82.6	2.5 %
Add			
Gasoline	13	25	5.5 %
Water power	8	18.2	7 %
Net energy consumption	83	125.8	3.5 %

The regional, even more than the end-use approach, tends to understate future requirements. Exceptional industrial developments are even more difficult to forecast in the case of individual areas. Also regional statistics pertaining to energy consumption are frequently deficient. Interprovincial movements, especially those pertaining to fuels which are employed by the railways and on the highways also tend to obscure such long-run relationships as might otherwise come to light in an analysis of this kind. Lacking supporting evidence, the estimates prepared in this way are usually conservative. For this reason no attempt was made, using the regional approach, to prepare a national projection to 1980.

Section III: Supply Estimate and the Commission's Forecast

The Supply Estimate

In Part B the markets for the individual energy commodities were examined in some detail and supply projections were made both on the basis of historical growth rates and of future market demand. When brought together these individual forecasts provide yet another method for considering the future energy requirements for the nation. These commodity forecasts have been assembled in the following table:

Canada's Energy Requirements in 1980 [a]

Energy source	Volume	Millions of tons of coal equivalent	Percentage each source
Coal	55 million tons	55	16
Petroleum	700 million bbl.	150	45
Natural gas	2,000 billion cubic feet	75	22
Natural gas liquids	60 million bbl.	9	3
Water power	300 billion k.w.h.	38	11
Nuclear energy	43 billion k.w.h.	6	2
Wood	3 million cords	2	1
Total		335	100

[a] As set out in Part B.

The Commission's Forecast

The several projections of energy demand and supply which have been made in the preceding paragraphs are tabulated below. The average of these various projections is, in our view, the best expression of the volume of energy which will be required to meet the demands of the nation by 1980. (See chart: Consumption of Energy in Canada 1926-1980). Considering the methods employed the range of estimates is surprisingly small. Four of the five estimates are within 10% of the average, the fifth being within 15% of the 300 million tons of coal equivalent selected as the most likely to be needed in 1980.

Forecasts of Energy Requirements 1980

Method	Millions of tons of coal equivalent	Rate of growth
Projection of gross supply	260 - 290	3.5 % - 4 %
Forecast of G.N.P.	265 - 310	3.5 % - 4.25%
Forecast of labour force	260 - 315	3.5 % - 4.25%
Sector analysis	280	3.75%
Regional analysis	275	3.75%
Supply analysis	335	4.5 %
Commission's forecast	300	4.25%

The most probable division of the energy market among the various sources as obtained from the last of these analyses is as follows:

Energy Requirements 1980

(each source as percentage of total supply)

Coal	Oil	Natural gas and natural gas liquids	Water power	Nuclear energy	Wood
16	45	25	11	2	1

These proportions pertain to energy inputs, *i.e.* coal, oil, natural gas, water power, etc., in their raw state. Yet losses occur at all levels depending upon the type of energy employed and on the particular uses to which it is devoted.[2] Currently between 55% and 60% is wasted. Only 42% of Canada's total energy supply was used effectively in 1953.

It is expected that, over the next 25 years, a further improvement in efficiency will take place. Of the nation's greatly expanded energy supply in 1980 slightly more than half will accomplish useful work or produce useful heat. In other words the next 25-year efficiency gain—still measured in national terms—may be in the order of 20%. If realized, it will be only slightly less than the improvement in efficiency experienced in Canada from the late 1920's to date.

In the final table in this chapter the various energy sources have been ranked according to their effective contribution in the economy. Those which perform the greatest amount of useful work or supply the most heat appear as higher percentages. Those whose effective output is least appear as less important on the output scale.

Relative Importance of Energy Sources in 1980
Ranked According to Useful Energy Obtained

(% contribution each source)

Coal	Oil	Natural gas and natural gas liquids	Water power	Nuclear energy	Wood
13	34	25	23	4	1

It is interesting to note in this connection that water power will move ahead of coal over the next quarter century. Electricity from all sources, including hydro and nuclear power stations, will continue to be more important than natural gas. Oil, as now, will lead all others in both raw input and effective output terms.

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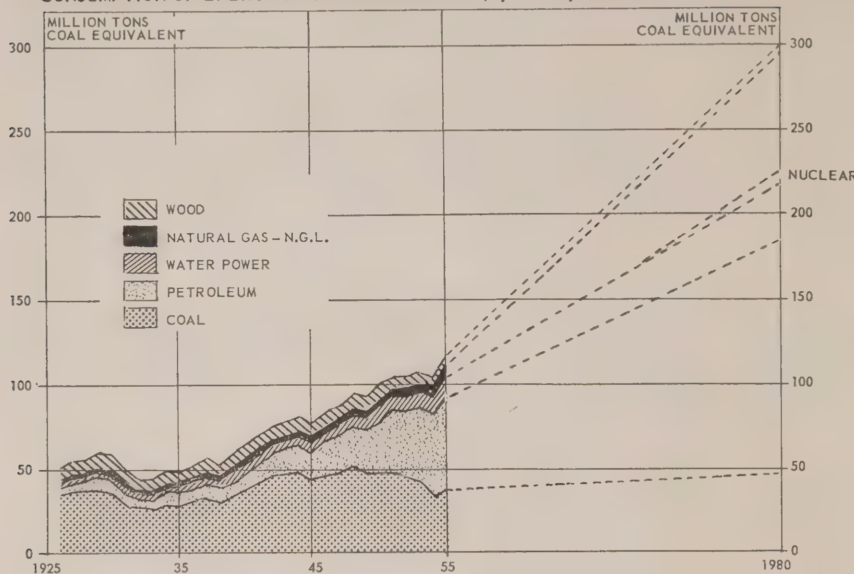
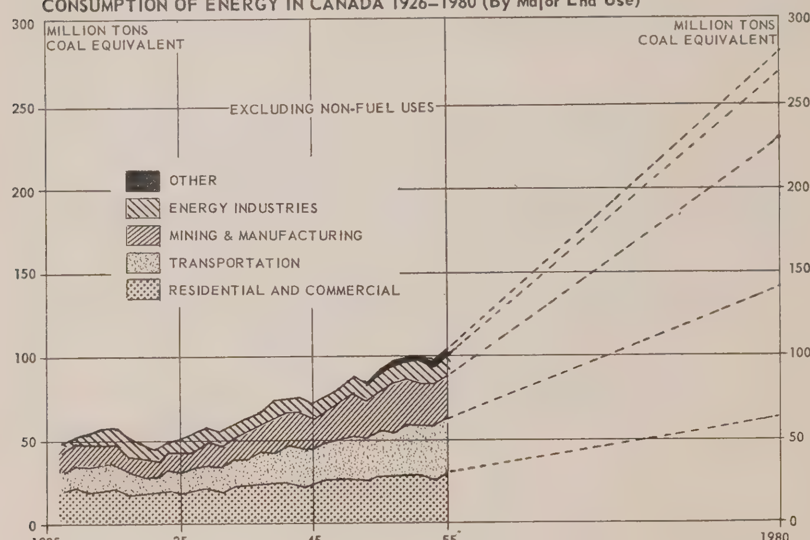
[2]Reference has been made to the concept of useful energy in earlier chapters. In Chapter 4 it was remarked that in 1953 coal supplied approximately 32%, petroleum 39%, water power 19%, natural gas 5% and wood 5% of all the energy put effectively to use in that year. See also Appendix D.

CONSUMPTION OF ENERGY IN CANADA 1926–1980 (By Primary Source)



CONSUMPTION OF ENERGY IN CANADA 1926–1980 (By Major End Use)



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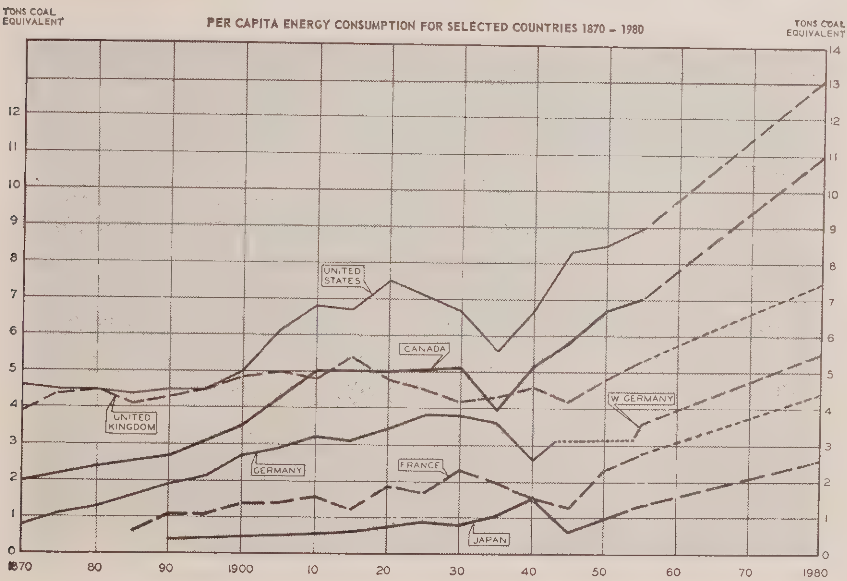
A COMPARISON WITH PROJECTIONS FOR OTHER COUNTRIES

IN RECENT years a number of countries have become increasingly concerned about their energy supplies. Others, impressed by the rate at which consumption has been expanding, have attempted to make more efficient use of the fuel and power resources within their own immediate control. Recognizing the importance of energy in economic development, international agencies have also carried out comprehensive studies of a technical and economic nature. Conferences have been called and a great deal of historical and forward-looking information has become available. This can be turned to advantage in forecasting the outlook for energy in Canada. (See chart: Per Capita Energy Consumption for Selected Countries 1870-1980.)



The range of prophecy is wide. Compound annual increases of 5% or more have been projected more or less indefinitely for the U.S.S.R., certain of its satellites and for the majority of the Latin American countries. The long-run demand growth rate in Western Europe is meanwhile expected to be in the order of 2.5%[1] Falling midway between is a long-run forecast recently published by the United Nations.[2] It selects a 3.5% yearly increase in consumption as the one most likely to persist throughout the world as a whole during the 1960's and 1970's.

Individual cases are interesting in that their tendency to run above or below this 3.5% norm can frequently be traced to one or two dominant influences. Among those leading towards a higher than average rate are a greater emphasis on primary processing, a relative decline in efficiency in use (such as accompanies a shift from hydro to thermal power), and exceptional increases in population and labour productivity. Holding consumption in check, on the other hand, are developments which lead more to secondary manufacturing and commercial activities, such improvements in efficiency as frequently accompany the greater use of liquid fuels, a tendency to import rather than export fuel and finally a slower rate of economic growth as measured by some such indicator as G.N.P. The United Kingdom, belatedly converting from coal to oil, is at one extreme. Energy demand there is forecast as rising at around 2% per annum over the next quarter century. Certain of the Middle Eastern countries are at the other. Some like Israel, whose population and labour productivity are rising rapidly, or Kuwait, where oil production and processing is overwhelmingly important, are experiencing sustained rates in excess of 10% a year.

For Western Europeans it is the middle range which holds the greatest interest. Most French authorities expect the 3% rate to prevail in their country through to 1975. Switzerland, despite the fact that many of her hydro-electric power resources have already been developed and the majority of her fuel needs have to be imported, anticipates that a long-run rate of 3.3% will prevail. The Scandinavians are more optimistic still. Official figures recently released by Sweden indicate a probable 3.5% rate through to 1980. A comprehensive study released by the O.E.E.C. early in 1956 listed West German requirements as in the order of 4% compound over the next two decades. In view of these well considered expectations a yearly rate for Canada of 4% or even 4.5% a year does not appear unreasonable.

[1]The latest O.E.E.C. forecast for Western Europe envisages a 2.9% maximum, 2.5% medium and 2.1% minimum growth rate as prevailing through 1975. (See *Europe's Growing Needs for Energy—How can they be met?*, Paris, 1956.

[2]Proceedings of the International Conference on the Peaceful Uses of Atomic Energy Vol. 1—*World Energy Requirements*, Geneva, 1955.

A point of reference is often to be found in statistics pertaining to the United States. The best-known United States projection, that of the Paley Commission published in 1952, envisaged a 3% annual rate trending upward from 1950 to 1975.[3] Based upon assumptions as to population growth and improvements in productivity which now appear to have been unduly conservative, it has had to be revised upward. The United States Department of the Interior has more recently come up with a slightly higher forecast of around 3.25%. Various individuals and organizations reviewing recent trends have been inclined to go even higher. These views, reinforced by the knowledge that energy may become more readily available in Canada over the next 25 years lends additional weight to the arguments used for choosing 4% as outlined at the end of Chapter 6.

Forecasts of energy requirements can be derived more or less directly from a projection of G.N.P. In earlier and less sophisticated studies the two were assumed to run in parallel. Thus, a 1% increase in G.N.P. resulted in a comparable rise in the demand for fuel and power. A closer examination of the facts often discredits such a highly simplified view of things. Usually energy inputs have lagged somewhat behind this all-inclusive measure of economic growth. In Western Europe a 1% rise in G.N.P. has, over the past decade, been accompanied by a 0.8% increase in energy demand. American analysts working in this field envisage 0.85 to 0.90 as being more relevant to the next two or three decades in the United States. Our own forecast is for a ratio starting at 0.85 and rising progressively to 0.95 during the 20-year to 30-year period under review. On the average over the next 25 years this is equivalent to a 0.92% rise in energy requirements for every 1% rise in Canadian G.N.P.

A shift in emphasis between uses often has (and in Canada's case will have) a good deal to do with the rate at which national energy requirements continue to change. The accompanying table—besides illustrating that usage, use sector by use sector, in this country will more nearly approximate that of North America as a whole—indicates that consumption by end-use in this country in 1980 may resemble that of the United States in the late 1940's. The main differences may be proportionately greater requirements in manufacturing and less energy used (relative to the total) in households and commercial establishments.

The most noticeable change is the increasing importance of the energy industries themselves as energy consumers. As a larger share of the total energy supply is processed, refined, or converted before use, the energy required for and the losses ensuing from these operations increases rapidly. More than 75% of the electric power supply is generated by thermal stations in the United States and, consequently, conversion losses are relatively much greater than in Canada. In all the major end-uses, however,

[3]See *Resources for Freedom* Vol. III, released by the U.S. President's Materials Policy Commission, June, 1952.

Energy Consumption by End-Use
(as percentage of total energy supply[a])

Major End-Use	Canada				United States			
	1929	1939	1953	1980	1929	1939	1947	1975[c]
Energy[b]	7	8	11	15	16	17	18	30
Manufacturing	20	20	24	31	24	22	23	24
All transportation	29	27	30	28	29	30	28	20
Domestic and commercial	40	42	30	23	28	28	29	23
Other fuel uses	4	3	5	3	3	3	2	3
Total	100	100	100	100	100	100	100	100

[a]Excluding, for reasons of comparability, non-fuel uses.
[b]Production and conversion.
[c]Paley Commission forecast.

the long-term trends in Canada correspond to the long-term trends of energy in the United States. (See also accompanying chart entitled, Relative Importance of Energy Sources—United States and Canada, for a comparison of energy source projections.)

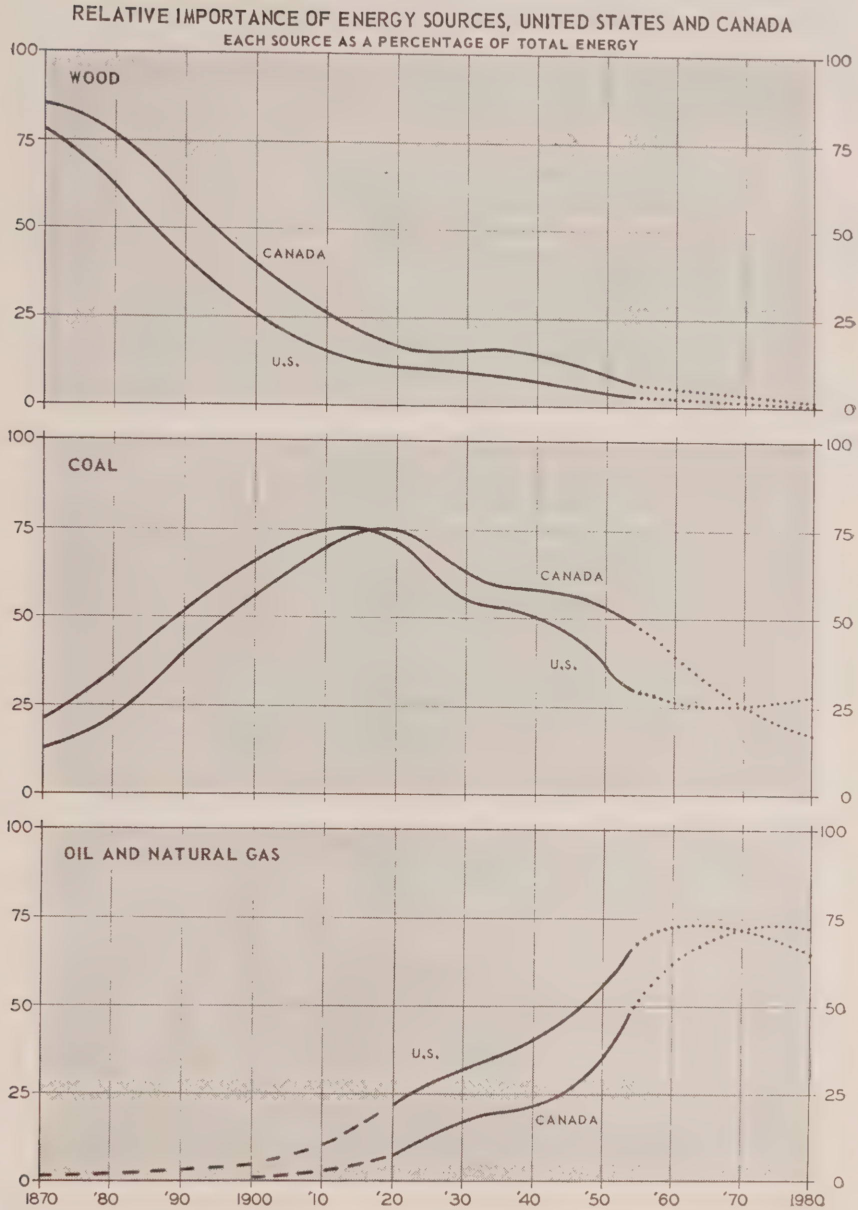
In all the more highly industrialized countries, oil and natural gas are expected to make the greatest contribution to growth. Coal, for a time, may fall or approximately hold its own. Eventually, thermal means must be found to supply most—if not all—of their electricity needs. Because of the relative abundance of liquid fuels and hydro power and the lack of indigenous coal resources near Canada's major industrial centres, greater reliance is likely to be placed on these more desirable forms of energy than in the United States and most parts of Western Europe. Nuclear energy, meanwhile, may make a more modest contribution to total energy demands in Canada.

Relative Importance of the Primary Sources in 1980
(percentage of total supply)

Country or region	Coal	Oil	Natural gas[c]	Water power[d]	Nuclear[d] etc.
Canada	16	45	25	11	3
United States[a]	29	38	27	1	5
Western Europe, 1975[b]	55	34	2	4	5

[a]U.S. Bureau of Mines, 1955.
[b]*Europe's Growing Energy Needs,* O.E.E.C. Report, 1956.
[c]Including the natural gas liquids.
[d]Water power and nuclear energy are measured in terms of their contribution as electricity; nuclear percentages are based on 1957 estimates.

Even more informative are the expected annual growth rates. In most cases, the utilization of coal is expected to rise less than that of energy as a whole. The demand for natural gas, meanwhile, is forecast as rising



CANADIAN FORECASTS – THIS COMMISSION; FOR THE U.S. – U.S. BUREAU OF MINES

at rates of 3% or more even in economies like the United States which already use it extensively. Oil may go up at around 4% or even 5% while the contribution of water power and nuclear energy will depend much more on such supply considerations as remaining undeveloped resources and the contribution of technology towards reducing the cost of electricity generally.

Forecast Annual Rates of Increase in Demand
(percentage per annum)

	Coal	Oil	Gas	Water power	Total energy
Canada (1955-80)	2.0	4.5	9.0	6.0	4.0
United States (1955-80)[a]	2.5	3.0	3.5	2.5	3.0
Western Europe (1955-75)[b]	0.5	5.0	7.0	4.0	2.5

[a]U.S. Bureau of Mines, 1955.
[b]O.E.E.C. Report, 1956.

15

IMPLICATIONS FOR THE REST OF THE ECONOMY

THERE is no simple way in which the economic effects of a given industry or group of industries can be measured with accuracy. Statistics relating to their gross value of production are too comprehensive in that they include expenditures on goods and services produced in other sectors. Net value of production as reported by D.B.S. excludes only outlays on raw materials, fuel and electricity. It therefore exceeds the true value added by each industry to the extent of depreciation and payments for such business services as advertising. Data on salaries and wages, on the other hand, tend to understate its contribution. They make no allowance for the fact that capital and certain other resources internal to the industry's operations are also vital to its continuance.

Recognizing these shortcomings, attempts have been made in Canada and elsewhere to carry out a complete and internally consistent input-output analysis of the national economy, major sector by major sector and industry by industry. In so far as possible the latter approach has also been adopted in the following analysis.

Comparisons in respect to international trade are useful. Yet dollar values are, again, gross values. Also commodity exports, regardless of their nature, are valued at their point of origin; not at the International Boundary. Hence, in circumstances where an industry is integrated to the extent that it not only produces but also transports its products to their destination outside of Canada, they therefore understate its contribution as an earner of foreign exchange. Import figures are different again. As published in *Trade of Canada,* they reflect the invoice price at point of entry. Provision for freight, insurance and handling charges, and duties and other taxes must consequently be made if the delivered cost to the importer is to be properly evaluated.

Industries which purchase some part of their raw materials abroad, buy some of their machinery and equipment elsewhere, or are owned outside of Canada, further complicate matters. Tending to offset the sale of the

industry's products outside of Canada are foreign expenditures on supplies and equipment and the payment of interest and dividends abroad. Allowances of this kind must therefore be made if the industry's net earnings of foreign exchange are to be properly assessed.

Investment expenditures covering new construction and the purchase for the first time of plant and equipment are also significant. However, as reported by D.B.S., they do not include amounts spent on such other transfer payments as the purchase of land, buildings and other existing physical assets. In some instances they therefore fall short of the industry's own balance sheet accounting of capital investment by as much as 10% or even 20%. Also there is the matter of import content. The direct effect upon the Canadian economy of an investment programme, the associated demands of which are essentially for the services of Canadian contractors and Canadian building materials and equipment, is obviously greater than another of comparable size whose capital goods are largely produced elsewhere.

In this chapter, each of these measures is reviewed in turn. Where possible each industry's output has been measured in terms of Gross Domestic Product—an approximation, which itself, is directly comparable with such economic aggregates as G.N.P. However, since detailed input-output analyses have only been carried out for the year 1949, such long-run series as net value of production, employment, commodity exports and new capital investment have frequently been used in their stead.

Value of Production

Forward looking estimates of production have already been discussed in volume terms. In order to convert these into dollar figures, price estimates have also been prepared. A rise relative to the general price level results, naturally enough, in even higher value figures; no change in real price in a parallel movement in output values; and, where applicable, a decline in relative price in a falling behind of the value of production series.

The following table summarizes the information available for 1955 and includes estimates for 1980. It indicates that the gross value of output of Canada's energy industries may increase to approximately five times its present level over the next quarter century. Sales of fuel and power in their raw or semi-processed or fully-processed forms may rise from around $1.9 billion in 1955 to about $10 billion 25 years from now. Currently the value added at all levels, from transportation and processing to distribution and marketing, is equivalent to about 7% of the nation's G.N.P. Since the Canadian economy will be growing at a lesser rate over the next quarter century, the energy sector will be growing relatively in importance. In value terms it may be equivalent to around 13% of G.N.P. in 1980.

Estimated Value of Production
Canada, 1955 and 1980

(value in millions of 1955 dollars)

Industry category	1955 ($ millions)	1980 ($ millions)
Exploration, development and primary production (gross value)	450	3,250
Processing, conversion and power generation (net value)	710	3,000
Transportation, distribution and marketing (net value)	725	4,000
Grand total	1,885	10,250

Most striking changes will take place at the primary (or mining) and in the tertiary (or distribution and marketing) areas of activity. Stimulated by the increased search for oil and natural gas, primary output may multiply about sevenfold. A goodly part of this increased activity will be export induced. Meanwhile, the combined value of transportation, distribution and marketing may reach more than five times their present level. Here electric power, followed by natural gas, is likely to make the greatest contribution to growth. Developments in the secondary (or processing) phase, are only less marked by comparison. They may multiply fourfold or more over the next 25 years.

If one ignores the finding and producing phases of liquid fuel production and concentrates on processing and marketing it turns out that the value added by the electric power utilities will become commensurate with the combined refining, transportation and distribution operations of the oil and gas industries in 1980. The fact that domestic requirements for electricity may continue to grow at an annual rate of around 7% as compared with 5% in the case of most petroleum products, is largely responsible for this.

Estimated Gross Domestic Product (at Factor Cost)
Canada, 1955 and 1980

(value in millions of 1949 dollars)

Category	1955 ($ millions)	1980 ($ millions)
All energy industries	970	5,000
Total Canadian G.D.P.	19,390	55,400
Energy industries/total Canada	5	9

These statistics, though they give an impression of relative rates of growth, must be reduced to the extent of purchases from other sectors of the economy if they are to be used in a direct comparison with Gross Domestic

Product. Such a conversion as is made in the following table also indicates that Canada's energy industries are likely to grow relatively in importance. Accounting for around 5% of the total economic activity in this country in 1955, it may rise to around 9% in 1980.

Employment

Another and more tangible measure of growth is direct employment. The nation's energy industries currently provide full-time jobs for some 157 thousand Canadians. Based on the estimates of physical output reported elswhere in this study and the assumptions as to further improvements in labour productivity outlined in the next table, employment in the finding, production, processing, transportation, distribution and marketing phases of the nation's fuel and power industries may amount to between 350 thousand and 400 thousand persons in 1980. In its national perspective, this performance is less striking than the outlook with regard to production. Twenty-five years hence about 3.7% of the nation's total labour force will be working in these industries as compared with about 3.2% at the present time.

The extent of these changes will vary from one level to the next. The number of workers employed in the primary activities (*i.e.,* in exploration and development and production) may increase by about 60%. Employment on the woodlots, at the mines and in the oil and gas fields may rise about as fast, but no faster than, population. In the secondary or processing stage a two to threefold expansion is anticipated. Headed by the power generating stations, natural gas processing plants and oil refineries, manufacturing may therefore offer more job opportunities than the stepped-up search for and production of oil and natural gas. In the transportation, distribution and marketing area there appears to be even greater scope for growth. Openings in this connection may approximately treble over the next quarter century.

Compensating forces will be at work. At the primary level the shutting down of coal mines and a dwindling market for fuelwood will release labour. This tendency will be more than offset by an intensification of the search for liquid fuel resources in western Canada. As far as processing is concerned, employment gains are expected to take place all along the line. More coal will be converted to coke, manufactured gas and electricity. Despite the effects of automation and a continuing marked increase in productivity, oil refinery operations may supply twice as many job opportunities as they did in 1955. Purification of natural gas will also provide more openings. Yet, generating stations owned by the electric power utilities may eventually provide more employment opportunities for Canadians than all the nation's crude oil refineries and natural gas processing plants combined.

In the service area, the retailing of coal and fuelwood may virtually cease. On the other hand the transmission, distribution and marketing of electricity and natural gas will become major employers of labour. The power utilities, between them, may provide jobs for as much as one-third of all the Canadians employed in the fuel and power sector of the economy a quarter century from now.

It is difficult to obtain a measure, in terms of employment, of the activities which will be dependent essentially upon export demand. Exploration and development, primary production and mainline transmission are the sectors involved. Since only about one-third of all the oil and natural gas produced in Canada in 1980 will be sold elsewhere it can be surmised that job opportunities for fewer than 30 thousand Canadians will be directly dependent upon export sales of energy 25 years hence.

Estimated Employment in the Energy Industries
Canada, 1955 and 1980

Industry category	1955 (thousands)	1980 (thousands)	Assumed annual rate of increase of labour productivity
Exploration, development and mining	62	100	3.0%
Processing, conversion and power generation	24	67	3.0%
Transportation, distribution and marketing	71	200	2.0%
Grand total	157	367	2.5% (approx.)

Capital Investment

A more impressive measure of the prospective growth of Canada's energy industries is capital investment. Currently the nation's fuel and power industries are investing \$1 out of every \$7 presently being spent on the creation of new physical assets in Canada. In 1955 more than \$900 million was invested in exploration and development, production, processing, transportation, distribution and marketing in this country. Over the next quarter century this effort may increase to more than five times its present level. Thus, between \$4.5 billion and \$5.0 billion may be spent annually on the search for additional resources and new plant and equipment necessary to expand domestic consumption and exports in 1980.

If this is so, investment in the energy sector will increase relative to total invesment in all industries in Canada. At the present time about 25% of all the capital being raised for this purpose in the industrial sector is being invested by individual firms and corporations concerned primarily

with the production and marketing of energy. The relationship to the national industrial total might be more like 40%, 25 years from now.

New capital outlays are likely to increase most at the primary level; less so with respect to processing and distribution. Moneys spent on finding, development and primary production may be six or seven times that devoted to the establishment of fresh resources at the present time. Investments aimed at the expansion of oil refining, gas processing and electric power generating facilities may go up three or four times. Transportation, distribution and marketing meanwhile may call for five times as much capital in 1980.

Estimated Value of New Investment in the Energy Industries Canada, 1955 and 1980

(value in millions of 1955 dollars)

Industry category	1955 ($ millions)	1980 ($ millions)
Exploration, development and primary production	275	1,800
Processing, conversion and power generation	335	1,350
Transportation, distribution and marketing	320	1,650
Grand total	930	4,800

Though the investment outlays of the oil and gas companies tend to dominate these calculations, the power utilities will also be faced with the task of raising unprecedented amounts of capital. Of total new investment in the Canadian energy sector in 1955 that spent on new power generating plants, transmission grids and distribution systems amounted to about $425 million (or 45% of the total). In 1980 the nation's power utilities may have to invest something like $2 billion each year in order to keep up with the annual increase in demand for electric power. The oil and gas industries by comparision may be investing between $2.5 billion and $3.0 billion a year a quarter of a century from now.

One of the most significant characteristics of the energy programme is its import content. Many of the specialized engineering services and much of the machinery and equipment employed by the oil and gas industries will continue to be purchased elsewhere. Thermal power generating equipment, numerous steel items and the services of market and other consultants will also continue to be purchased in the United States, the United Kingdom and Continental Europe.

The import content of the average Canadian project is now around 25%. This will decline as a greater proportion of the necessary technical services, machinery and equipment and construction materials become available

from Canadian sources. In 1980 imports might be valued at around 15% of total capital investment. Due to the size of the over-all programme, some $700 million worth of foreign exchange would then have to be found to cover the purchase of capital goods in other countries.

Total capital investment, as we have seen, may rise to between five and six times its present level by 1980. The impact of this expenditure on the Canadian economy will be even greater due to a proportionate rise in Canadian content. Were the latter to rise from an average of 75% to more like 85% of total capital outlays on fuel and power account in Canada, this could result in a better than sixfold multiplication in investment generated activity in Canada over the next quarter century.

Balance of Trade

Already export developments in respect to oil and natural gas are having a noticeable effect upon Canada's balance of trade. Exports are beginning to rise and imports to fall. Expenditures of foreign exchange on fuel and power commodity account exceeded earnings to the extent of a half billion

Table 20

ESTIMATED VALUE OF PRODUCTION[a] CANADA, 1955 AND 1980

	1955 ($ million)	1980 ($ million)
Primary		
Fuelwood	40	25
Coal	90	100
Crude oil	303	2,500
Natural gas (clean dry)	15	500
Natural gas liquids	2	125
Total	450	3,250
Secondary (value added)		
Coal processing (coke and gas)	55	150
Oil refining	350	1,000
Gas processing	5	100
Power generation	300	1,750
Total	710	3,000
Tertiary or service (value added)		
Coal and wood distribution	30	25
Oil pipelines	60	500
Oil marketing	300	1,000
Gas pipelines	10	475
Gas distribution	25	500
Power transmission and distribution	300	1,500
Total	725	4,000
Grand total	1,885	10,250

[a]In 1955 constant dollars.

dollars as recently as 1950. Even in 1955 Canada's energy commodity balance was unfavourable to the extent of $438 million. Currently exports of energy account for less than 5% of the nation's total commodity sales abroad. Imports of crude oil, petroleum products and coal, meanwhile, are equivalent to about 11% of all goods bought elsewhere for domestic consumption.

The outlook for 1980 is encouraging. By then sales, particularly in the United States, of crude oil, natural gas and electricity may push Canadian earnings of foreign exchange up towards the $2 billion mark. Imports, meanwhile, may little more than double. Canada would then have a favourable trade balance on energy commodity account to the extent of approximately $1 billion. Under these circumstances sales elsewhere would account for between 15% and 20% of total Canadian visible exports. At the same time purchases outside the country of fuel and power might decline to around 10% of the value of Canada's imports of all commodities.

Table 21

ESTIMATED EMPLOYMENT IN THE ENERGY INDUSTRIES CANADA, 1955 AND 1980

	1955	1980
Primary activity		
Fuelwood	30,000	10,000
Coal mining	16,000	10,000
Oil development; production	15,000	80,000
Gas development; production	1,500	
Total	62,500	100,000
Secondary activity		
Coal processing	3,500	6,000
Oil refineries	13,000	25,000
Gas processing	300	6,000
Power generation	7,000	30,000
Total	23,800	67,000
Tertiary (or service) activities		
Coal and wood distribution	10,000	4,000
Oil pipelines	1,200	6,000
Oil marketing	30,000	65,000
Gas pipelines	500	5,000
Gas distribution and marketing	2,000	30,000
Power transmission, distribution and marketing	27,000	90,000
Total	70,700	200,000
Grand total	157,000	367,000

In order to be comprehensive some allowance must be made for purchases elsewhere of engineering services, machinery and equipment, construction materials etc. Also additional demands in the form of interest payments and dividends paid to non-resident investors in the Canadian

fuel and power industries must be taken into account.[1] Collectively these items are likely to be such as to approximately offset the $1 billion surplus on commodity account forecast for the average year 20 to 30 years in the future.

Table 22

ESTIMATED VALUE[a] OF NEW INVESTMENT IN THE ENERGY INDUSTRIES CANADA, 1955 AND 1980

	1955 ($ millions)	1980 ($ millions)
Primary		
Coal, fuelwood	7	20
Crude oil	266	1,530
Natural gas	2	250
Total	275	1,800
Secondary		
Coal processing (coke and gas)	4	12
Oil refining	103	288
Gas processing	3	50
Power generation	225	1,000
Total	335	1,350
Tertiary or service		
Coal and wood distribution	n.a.	—
Oil pipelines	28	75
Oil marketing	54	200
Gas pipelines	18	75
Gas distribution	20	250
Power transmission and distribution	200	1,050
Total	320	1,650
Grand total	930	4,800

[a]In constant 1955 dollars.
Commodity import content of new capital investment: 1955 = 25%; 1980 = 15%.

Table 23

ESTIMATED VALUE OF EXPORTS 1955 AND 1980

	1955 ($ millions)	1980 ($ millions)
Coal	6	50
Crude oil	36	1,500
Petroleum products	4	25
Natural gas	1	200
Electricity	11	75
Total energy exports	58	1,850
Total Canadian exports	4,332	11,000
Energy as a percentage of total exports	1.4	16.9

[1]Dividends paid to owners may be assumed to be equivalent to about 20% of annual capital expenditures; see *Investment Patterns in the World Petroleum Industry*, p. 26, Chase Manhattan Bank, December, 1956. This is average experience over the past five years in the United States.

Table 24

ESTIMATED VALUE OF IMPORTS 1955 AND 1980

	1955 ($ millions)	1980 ($ millions)
Coal and coke	114	300
Crude oil	229	250
Petroleum products	150	450
Natural gas	3	25
Electricity	1	25
Total energy imports	497	1,050
Total Canadian imports	4,540	10,440
Energy as a percentage of total imports	10.9	10.0

Energy commodity trade balance:
Imports/Exports in 1955 = $438 million.
Exports/Imports in 1980 = $800 million.

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GENERAL OBSERVATIONS

FORECASTS, however compiled, reflect the various assumptions upon which they are based. Those described in this study are no exception. They will be altered materially should the Commission's premises as to no all-out war, a continuing high level of employment and no marked changes in Canadian government policy, be overthrown by future events. They would also be disturbed were scientific or engineering developments of a revolutionary character to make their appearance during the forecast period under review. The foregoing forecasts, both of aggregate energy demand and in respect to individual commodities, would therefore have to be adjusted upward or downward depending upon the pace of technological developments. In this concluding chapter an attempt has been made to quantify the possible effect of these unforeseen developments; happenings which by their very nature could alter both the magnitude and direction of these trends in the late 1960's and 1970's.

Of first importance is the assumed level of Canadian economic activity. Domestic requirements will be higher or lower depending upon the nation's future output of goods and services. Were the Commission's minimum assumptions as to population increase (25 million in 1980) and labour productivity (*i.e.* 2.5% per annum) to apply, the demand for energy—rather than being some 2.7 times the 1955 volume in 1980—might multiply 2.4 or 2.5 times over the next quarter century. On the other hand, should Canada's population reach 28 million and productivity increase at the much higher rate of 3.25% per annum, the nation's over-all requirements might be 3.2 times its 1955 level 25 years from now. Therefore, depending upon future developments with regard to G.N.P. we have a range of forecasts varying 15% either way from that described at the end of Chapter 7.

Total expenditures on energy in Canada will rise or fall relative to G.N.P. depending upon (a) the relative movement of volume requirements and (b) the trend upward or downward in real price at the consumer

level. The accompanying forecasts indicate that Canadian energy requirements, when measured in physical terms, will rise somewhat more slowly than the G.N.P. It is also expected that the delivered price of energy will fall relative to that of other goods and services. The combined effect will therefore be to reduce total expenditures on fuel and power in Canada relative to economic activity in general. It is estimated that purchases at the wholesale and retail level will fall from approximately 10% of G.N.P. to around 8% of the total value of all goods and services produced in Canada in 1980.

Meanwhile, the tendency in the United States may be for total expenditures on energy to remain about the same relative to that country's G.N.P. Physical requirements (*i.e.* B.t.u.'s or tons of coal equivalent) may continue to lag somewhat behind economic activity generally. On the other hand the delivered price of energy may begin to rise relative to that of other goods and services in the United States. On balance, total outlays on energy in the United States may continue to run at between 6% and 7% of G.N.P. Were these expectations to be realized, the Canadian position would begin to approximate (but probably still be somewhat above) the North American average 25 years from now.

A decline of 2% in user expenditures on energy relative to Canadian G.N.P. would, however, be of considerable economic significance. Spread uniformly over a 25-year period it would release a considerable volume of goods and services (roughly equivalent in magnitude to the nation's G.N.P. in 1955) for consumption or investment in other lines of activity. Productivity over-all would have been increased and G.N.P. in later years would be higher to the extent of several per cent than would have been the case had the real price of fuel and power remained unchanged and no improvement in efficiency of utilization taken place in Canada during the quarter century under review.

Prospective happenings in the field of technology have even greater relevance in respect to the demand for individual commodities. Developments in the field of nuclear energy, were they to be hastened along by several major scientific break-throughs, might reduce the over-all market for coal substantially and cause the upward trend in the sale of both oil and natural gas to moderate in the years ahead. Of even greater regional significance could be the position occupied by hydro-electric power. The ability of what are presently regarded as advantageous sites to attract new industry might therefore be reduced, or even eliminated, towards the end of the forecast period. Hydro-electricity, in other words, would be in lesser demand and its contribution to Canada's future energy requirements correspondingly curtailed.

Vis-a-vis coal, the impact of an accelerated nuclear energy programme would be felt where it hurts most; namely in the generation of electricity. Coal's largest single prospective market might in this way be cut down

substantially. Residual oil and natural gas, to the extent that they are also in high-cost energy areas for the production of electric power would also be displaced—at least for base load purposes. Nuclear installations specially built for the production of process steam might also reduce the sale of fossil fuels in large volume industrial applications where price is a major consideration.

Two major sectors will remain a preserve of the liquid fuels. Such uses as space heating, which are highly seasonal in character, or railway use and highway transportation, in which mobility is at a premium, are less likely to be affected by unforeseen developments with respect to the harnessing of nuclear energy.

A common expectation is that nuclear energy will be a boon to both underdeveloped nations and outlying areas like northern Canada. This is not necessarily so. It looks now as if the nuclear power plants of the future will spring up first in and around the more highly industrialized centres and, by helping them to overcome their energy problems, contribute along with many other factors to the further centralization of economic activity. Various technological, financial and market factors are already working in this direction. Given a source of energy—a weightless fuel which can be transported at very little cost and burned in plants which can be set up anywhere—these tendencies are likely to be reinforced. Such locational influences as are still being exerted by the fossil fuels and water power resources would be further reduced. Other determinants, like the existence all in one place or area of a bulky and comparatively unique raw material, would be the only ones left to counter the pull of the market.

Capital costs, at least at the outset, will be high. Interest rates will, therefore, be an important determinant of economic feasibility. Where they are well above the average prevailing on this Continent, the cost of nuclear energy, either as electricity or process heat, will probably be prohibitive. This is true of much of South America, many of the African countries and of India and most of southeast Asia where political uncertainty is a contributing factor. There, interest rates below 10% are unheard of, whereas it might be possible to raise funds for this purpose for less than 4% in Canada, the United States and a number of Western European countries. If we fall back on our assumption that half or more of our nuclear power costs will be of a capital nature, it looks as if the rates which will have to be charged in these lesser developed countries may be several times those for which it could be produced on this Continent, in the United Kingdom or in several countries in Western Europe.

There will also be a marked variation between countries due to the availability (or lack of) skilled labour, competent construction firms, suitable repair facilities and supporting manufacturing industries of the chemical and metallurgical type which are necessary to minimize fuel and other

operating costs. Processing charges in so far as they relate to exposed material will also differ from country to country. These are among the reasons why it may be erroneous to assume a rapid levelling out of power costs between regions merely because the cost of fissionable material from one part of the globe to another may be a negligible portion of the total.

There is yet another group of factors which may disturb this assumption of uniformity. These are the economies of scale—economies which follow from the fact that investment in nuclear stations and their auxiliary equipment may rise much more slowly than their generating capability. This is the same thing as saying that there will probably be an inverse relationship between the size of the market and the cost of atomic power. Those countries or localities which are able to absorb large blocks of new power would, therefore, be in the best position to minimize costs. But those whose demands are small, irregular or growing only slowly are likely to pay a heavy penalty for that reason.

Fuel deficient countries or regions where fuel costs are on the increase where money can be made available at comparatively low interest rates and where the supporting industry and technical competence are available, will have the greatest incentive to participate in these new developments. For instance, the United Kingdom will continue to press ahead in this field because its own ability to produce coal is limited and the remainder of its conventional energy requirements must be imported. To survive economically the United Kingdom must export. To export she must be in the vanguard of industrial progress; particularly in the fields of machinery and equipment. Power production is one of the most promising of these. Her future trade policy and those of her principal exporting firms will therefore be directed increasingly towards the manufacture and fuelling of atomic installations. Western Germany and Japan are other countries in a similar position. They can therefore be expected to be in the forefront in so far as the widespread use of nuclear energy is concerned.

In looking back over all that has been written several points stand out. Energy, in the physical sense, is not likely to be a scarce commodity. Neither will it become unduly expensive. As costs are reduced nuclear power and nuclear produced heat will set a ceiling on the price of alternative forms of energy. Technological developments, as yet unforeseen, may affect the forecasts outlined in earlier chapters. Yet they are unlikely to be such as to effect a major economic revolution. Limited by the rate at which new capital can be raised and invested, they may however bring about economies in the order of 1% or 2% of G.N.P. during the 20-year to 30-year period under review.

Meanwhile increased quantities of oil and natural gas will be moving from the major producing regions to the principal industrial areas of the world. Nuclear materials including uranium-235 and thorium will also be

in demand. Canada, besides providing for most of her domestic requirements, will have an opportunity to export a number of these commodities. Autarchy may one day be possible with respect to energy. However, over the next 25 years the materials essential to its effective application will probably gain relative to all other goods and services entering into international trade.

APPENDICES

Appendix A

TRENDS IN OIL EXPLORATION, DEVELOPMENT AND PRODUCTION COSTS

In order to assess Canada's competitive position as a producer of oil (and, to a lesser extent of natural gas) it was necessary to:

(a) obtain some idea of present-day costs of finding and producing oil in Canada, the United States and elsewhere;

(b) determine the direction in which these costs may move, one relative to the other, over the next two or three decades.

A detail cost study, prepared by H. J. Struth and published in *World Petroleum* in 1955 was used as a starting point. Descriptive of trends in the United States and covering the years from 1933 to 1955, it provided the necessary methodology for making a similar analysis of exploration and development, production and other costs in western Canada. Subsequently, two other American cost analyses became available. One, published in July, 1955, was by R. Granier de Lilliac and Gilbert Lugol. The other, the results of which were released early in 1956, (and hereinafter referred to as the Joint Survey) was carried out by the American Petroleum Institute, the Independent Petroleum Association of America and the Mid-Continent Oil and Gas Association. These findings, together with Canadian data and supplementary information on proven reserves, production and wellhead prices were used to build up rough comparisons of costs and profit between Canada and the United States for the years from 1951 to 1954.

The following results, though differing in some instances from estimates prepared at our request by the industry, lead to similar conclusions, namely that: (a) finding costs have been lower and production costs much lower in western Canada than in the United States and (b) tending to offset these advantages has been the lower return at the wellhead imposed by greater distance to markets, United States import tariffs, less revenue from the sale of natural gas and the longer payout period resulting from a greater measure of shut-in capacity.

As time passes, the relationships indicated in the following tabulation of costs will change. On balance, they should make Canadian operations relatively more profitable. The following observations, since they point towards an increasing competitive advantage for Canadian producers, are essentially consistent with the optimistic views regarding crude oil discoveries and production expressed earlier in this report.

Costs of Oil Exploration, Development and Production in Canada and United States 1951-54

	(dollars per barrel)		
	Canada	**United States**	
		A	**B**
Receipts	2.51	2.64	3.17
Discovery and acquisition cost	0.62	0.73	0.68
Development cost	0.41	0.43	0.81
Production cost	0.45	0.77	0.60
Cost before taxes	1.48	1.93	2.09
Margin before taxes	1.03	0.71	1.08
Rate of return before taxes[a]	8%[b]	7%	7½%

[a]The rate of return before taxes is based on a discounting of future worth.
[b]Based on long-term production cost of 65¢ a barrel.

NOTES: *Canada Cost Survey*—These estimates are based on studies by several companies, government agencies and industrial consultants, and represent average conditions for the four-year period 1951-54. The value of receipts is a four-year average of crude petroleum sales. Total discovery and development costs are divided by working interest reserves to give unit discovery and development costs. All customary exploration and development expenses are included. Although reservation fees and bonuses are charged to exploration, lease bonuses are charged to development. Working interest production is also used in computing unit production cost. (Average royalty rate taken to be 12.5%.) Reserve additions were based on the four-year average. All data apply predominantly to Alberta as oil industry activity was largely concentrated in that province during the period under review.

United States Cost Survey (A)—The exploration and development estimates are based on the studies of H. J. Struth and represent a weighted average for the four-year period, 1951-54. A working interest basis is used, with average royalty taken to be 15%. Production costs are for 1953 and are based on studies by R. Granier de Lilliac and Gilbert Lugol. Revenues are from crude petroleum only and apply to those United States crudes with which Canadian crudes must compete.

United States Cost Survey (B)—These estimates for 1953 are derived from the Joint Survey of A.P.I., I.P.A.A. and Mid-Continent Oil and Gas Association. Certain adjustments have been made: the deduction of service well costs from development expenditures, computation on a working interest basis and the deduction of royalties from production expenditures, the calculation of exploration and development costs in terms of average additions to reserves for the period of 1951-1954 rather than against production. Revenue in this survey is the sum of income from crude oil, natural gas, royalty owned by the operator and other lease revenues.

Since 1950, the typical Canadian producer has received less for his oil than his American counterpart. Serving more remote markets, unable to find an outlet for much of the natural gas he has found, and with the Canadian dollar at a premium, his net-back at the wellhead has been lower to the extent of 13¢ or more a barrel.

Between now and 1980 a number of influences will be at work, some tending to narrow and others to broaden this gap in receipts. A continuing

rise in exploration and development costs in the United States leading to higher wellhead prices there would help to raise the price netback at the wellhead in western Canada. This would be true particularly in circumstances where the main markets served were inland and, hence, protected by distance from offshore competition from the cheaper Middle East crudes. Inflation *per se*, possibly reinforced by a rise in price relative to other commodities would also help to reduce the penalty of the 10.5¢ United States tariff on crude petroleum. A ready market for natural gas and natural gas liquids will also have a beneficial effect, as would a parity, or less than parity, position of the Canadian relative to the United States dollar.

On the other hand, the need for Canadian oil to push outward to more distant markets would tend to widen the existing price differential. A further 10% reduction may be necessary to enter outlets of sufficient volume to match the capacity of the Canadian oil fields. In allowing for this one might, on balance, assume a continuation of the present Canada-United States wellhead price differential. Though perhaps unduly pessimistic on the Canadian side it provides us with revenue data against which the accompanying cost estimates can be assessed with greater confidence.

In recent years, discovery and acquisition costs in Canada have been 10% to 15% lower than those reported in the United States. This is a margin which may well widen with time as evidenced by H. J. Struth's studies for the United States, which show that initial finding costs are reduced when revisions in reserves are later allocated back to the year of original discovery. Exploration activity stimulated by expanding markets, and development drilling carried out as a result of government lease obligations or in response to greater demand, usually result in proving up more oil than is conservatively estimated to have been found at the time of discovery. In other words a greater number of barrels of reserves are actually found to exist per exploratory dollar spent than earlier calculations tend to indicate. Over-estimates of the per barrel costs of finding oil are not uncommon in new territory such as western Canada where exploration activity is continuing well ahead of development drilling.

This contention is substantiated by United States data (see Table 1 of this appendix) listing the cost of finding oil in the United States, year by year, between 1933 and 1954. In reporting the initial, as well as the revised, cost of finding oil, it shows exploratory costs, as originally computed, as being well above the long-run average expenditure devoted to finding of oil and natural gas. There is sufficient cost history in the United States to make such revisions. In Canada there is not. Consequently, the differences in exploration costs between the two countries may turn out to be larger than is now indicated.

Recent United States increases in discovery costs are also worthy of note. Should they persist—and United States producers argue vehemently that

this will be the case—they may result in a further comparative cost advantage for western Canadian producers. Western Canada discovery costs may rise, too, but not at the same rate as United States costs.

Development costs are also lower than in the United States. Here it should be noted that the Canadian analysis for the years 1951 to 1954 is somewhat more akin to that of the Joint Survey or B computation for the United States since the latter also reflects gas well expenditures and includes a more complete accounting of cash outlays in respect to the purchase of capital equipment, than was incorporated in the A computation.

Production costs in Canada, being confined to new fields, are well below the North American average. However, as the age of the Canadian fields increases, they will rise. Pumping will become more general, water drives may have to be used, and other special techniques will have to be employed to maintain efficient rates of output. Costs will also tend to rise as development activity takes place in the more isolated areas of western Canada. In calculating rates of return, it is therefore inadvisable to use recent experience. Rather, an expected long-run average rate should be employed. In the preceding analysis an average production cost of 65¢ a barrel was used instead of the 1951-54 Canadian average of 42¢. The underlying assumption, like that pertaining to development costs, is that Canadian and American experience will tend to run parallel, one following the course traced out by the other over the next quarter century.

By adding up the foregoing costs and deducting them from the initial accounting of receipts, we obtain an estimate of the industry's margin of profit before taxes. For the years 1951 to 1954, the net position in Canada appeared to be in the order of $1.03 a barrel; in the United States, it varied between 71¢ and $1.08. In order to relate this to investment, further assumptions had to be made as to the immediate marketability of Canadian and American oil resources.

During the next few years, wells in the United States will be flowing at rates approaching at times the maximum allowed by sound conservation practice. Canadian oil reserves, on the other hand, will be shut in to a greater extent. More oil, though discovered and partially developed, will remain idle in the ground in Canada. A lack of immediate outlets will be tying up capital—capital upon which interest and other charges, nonetheless, will have to be paid.

With only a moderate amount of their oil producibility shut in, the rate of return before taxes, enjoyed by companies in the United States, appears to have been in the order of 7% or 7.5%. In Canada the rate for the period 1951-54 was about 8%; this, even though a much greater proportion of the country's proven oil reserves was rendered idle by a lack of effective demand.

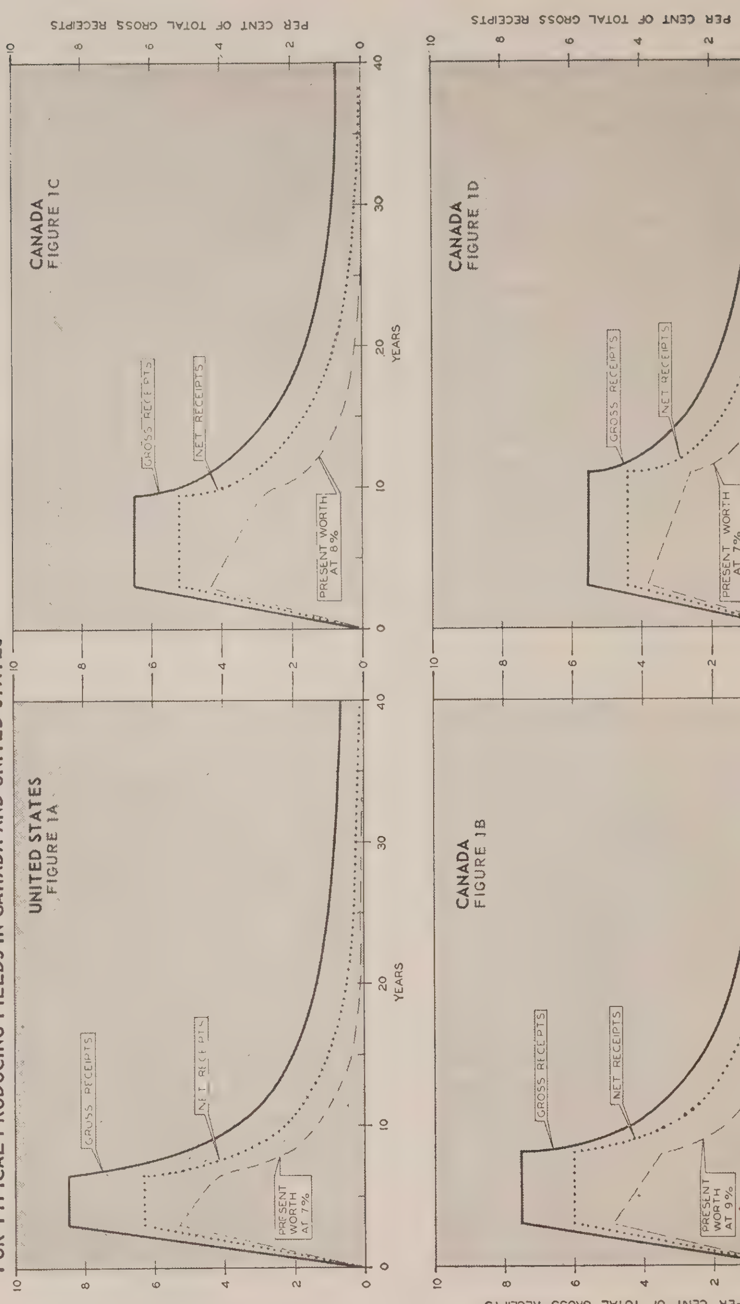
The chart: Oil Industry Revenue Assumptions for Typical Producing Fields in Canada and the United States shows curves used in computing the rate of return on investment before taxes. In Figure IA the curve of gross receipts is based on the average production curve established by R. Granier de Lilliac and Gilbert Lugol for a typical United States oil pool.[1] From the curve of gross receipts, royalty payments and production costs are deducted to give a curve of net receipts. By discounting the curve of net receipts at the appropriate rate, present worth of oil income may be equated to investment in exploration and development activities. For the typical United States oil pool the discount rate is computed at 7%, using cost and revenue data as set out for the A survey shown in the first table in this appendix. The curves are shown in Figure IA. Using the B Survey data, the discount rate becomes 7.5%.

In Figure ID similar curves are drawn for a typical Alberta oil pool based on 1951-54 cost and revenue experience. It should be noted, however, that the long-term production cost of 65¢ a barrel was used rather than the actual 1951-54 cost of 45¢. This results in a discount rate, or rate of return before taxes, of 7%. Production in Alberta has in the past proceeded at a much lower annual percentage rate in terms of oil reserves than has been the case in the United States due to inaccessability to adequate markets. Consequently Figure ID shows gross receipts in the early years of production to be at a much lower percentage rate than is the case for the United States curve in Figure IA.

It was considered that whereas the United States production experience over a period of time is typified in Curve IA, Curve ID may understate the typical Canadian oil field performance. Curves IB and IC present situations in which production proceeds at the rates of 7.5% and 6.5%, respectively, of total reserves for several years after the initial build-up period of three years, instead of at the rate of 5.5% as illustrated in Figure ID. While it might not be expected that oil reservoir withdrawals will take place in the early years at the rate of 8.5%, as illustrated in Figure IA for United States fields, it is quite possible that the 1951-54 experience in Canada may be below the average rate of production for a typical Canadian pool during the next 25 years. It thus is possible that a rate of return computed from such curves as are shown in Figures IB or IC should be used in making a comparison with the typical United States curves of income. The supposition set out in Figure IB indicates a rate of return of 9%; that of Figure IC, 8%. The conclusion reached in this study, as set out at the beginning of this appendix, is that a rate of return of 8% before taxes is representative of Canadian conditions which give fair comparison with cost and revenue experience presented by the typical United States curve shown in Figure IA.

[1] "Cost of Exploration and Production in the United States", R. Granier de Lilliac and Gilbert Lugol, *The Petroleum Engineer*, July, 1955, pp. B-40—B-62.

OIL INDUSTRY REVENUE ASSUMPTIONS
FOR TYPICAL PRODUCING FIELDS IN CANADA AND UNITED STATES



Over time and with expanding markets, the Canadian position cannot but improve. Since it is expected that, by 1980, oil originating on this continent will be a comparatively scarce resource, the foregoing analysis provides strong grounds for assuming that the funds necessary to support a large and expanding programme of exploration and development in this country will, in fact, be forthcoming.

Table 1

COST OF FINDING OIL IN THE UNITED STATES 1933-54

(three-year moving averages)
(value per working interest barrel)

	Current dollars		Index	Constant dollars	
	Initial	Revised	1926 = 100	Initial	Revised
1933-35	.169	.109	65.9	.256	.165
1934-36	.132	.087	74.9	.176	.116
1935-37	.134	.087	80.0	.167	.109
1936-38	.131	.106	80.8	.162	.131
1937-39	.157	.135	86.3	.182	.156
1938-40	.201	.189	78.6	.256	.240
1939-41	.279	.198	77.1	.362	.257
1940-42	.360	.281	78.6	.458	.358
1941-43	.442	.263	87.3	.506	.301
1942-44	.490	.278	98.8	.496	.281
1943-45	.527	.275	103.1	.511	.267
1944-46	.544	.305	104.1	.523	.293
1945-47	.564	.323	105.8	.533	.305
1946-48	.578	.360	121.1	.477	.297
1947-49	.554	.374	152.1	.364	.246
1948-50	.601	.425	165.1	.364	.257
1949-51	.626	.468	155.0	.404	.302
1950-52	.769	.588	161.5	.476	.364
1951-53	.886	.749	180.4	.491	.415
1952-54	1.073	—	171.7	.625	—

U.S. general wholesale prices index was used 1926 = 100.
SOURCE: Abstract of article by H. J. Struth, published in *World Petroleum*, July, 1955.

Appendix B

A NOTE ON TRANSPORTING ENERGY: COMPARATIVE COSTS

For consumers at some distance from sources of supply, transportation is an important item in the delivered cost of energy. Therefore, it is often a significant factor in determining the competitiveness of energy in the various forms in which it may be made available. The relative cheapness of ocean tanker and pipeline operation, combined with the other virtues of liquid fuels, has been instrumental in creating a global supply of these highly competitive forms of energy. But these methods of transport are still evolving, as are those used for the movement of other fuels. Is there any ready way, therefore, in which we can compare the cost factors involved in moving energy by tanker, by pipeline, by high tension wire, by rail and by collier? If so, what are the comparative cost advantages of each?

The choice of means depends on many considerations, including the ease with which carrying capacity can be enlarged, the degree of flexibility in meeting varying demands, the load factor, the directness or otherwise of the route followed and the cost of transport itself. An ocean tanker fleet has one great advantage, that of flexibility. Tankers can be moved from one trade route to another. In common with most other specialized transport vehicles, the tanker normally hauls a one way load. But the load factor—by which is meant the relation of peak use to average use—can be controlled, as seasonality in the demand for tanker transport can be met in large part by the provision of tankage at loading ports and destinations.

The capital cost of tanker transport, on the other hand, is heavy. A new tanker type vessel of approximately 16,000 tons costs about $5 million. A super-tanker of 30,000 tons deadweight would cost around $7.5 million. A desirable feature of tanker transportation is, however, that additional capacity can be constructed gradually and in relatively small increments.

In any appraisal of the value of alternative transport methods, the division between fixed and variable costs is important. Variable costs predominate the transport of petroleum by ocean tanker. In most British and Canadian vessels, labour, fuel and repairs comprise about 80% of the total. Labour cost of seagoing personnel, currently representing about 30% of total costs, have risen to such an extent in recent years as to practically offset the technical improvements in tanker design and construction. The cost of delivering light gravity oil coastwise by the newer, large tankers from the Caribbean up into the Maritimes and southern Quebec would appear to range from 1.0¢ to 1.5¢ a barrel per 100 statute miles.

When there is no restriction in the supply of materials, new, large diameter oil pipeline capacity can, at times, be constructed more cheaply than its equivalent in the shape of ocean-going tankers. Granted it is impossible to provide pipeline capacity for long distance movements in small increments, for the justification for long distance line may depend upon initial flows of up to 200 thousand barrels a day. Pipelines are also at a disadvantage in relation to tankers in that a pipeline route is inflexible. Hence, unlike investment in tankers, pipeline construction has to be justified on broad forecasts or assumptions as to the flow of traffic over a particular route for many years ahead.

The capital cost of large-diameter long distance pipelines is also high. For a 2,000-mile, 30-inch line the original investment may be in excess of $150 million. Unlike tanker transport costs, pipeline operating costs are largely fixed, the variable elements of the total cost of operation being within a range of 15% and 20%. The extra cost of transporting additional volumes of oil within the capacity of an established pipeline system is, therefore, small. In most cases, it is limited to additional pumping power costs and taxes. On this continent, delivery of a light oil over modern long distance 30-inch pipeline, operating close to capacity, can be accomplished for around 2.0¢ to 3.0¢ a barrel for every 100 miles.

Natural gas pipelines are subject to advantages and limitations similar to those of oil lines, but load factor is even more important, owing to much wider seasonal variations and demand than occur in respect to oil. The largest lines on this continent have required capital investments in the order of $300 million. The fixed costs of natural gas lines on the larger 30-inch to 36-inch lines fall within the bracket of 1.1¢ to 1.6¢ per thousand cubic feet per 100 miles.

High tension lines for the transmission of electrical energy have some of the economic characteristics of pipelines. However, the lines themselves can be built more quickly, and the flexibility of high tension line transmission lies somewhere between the flexibility of the pipeline and the extreme flexibility of tanker transport, with a position somewhat closer to the latter. Movements of electric power, however, do not usually exceed 300 miles, although there are already important exceptions to this rule. Load factor considerations are often crucial. Fluctuation in demand for power is a major problem since electrical energy cannot be stored. Also, the original cost of high tension electric lines is relatively high, and, as in the case of pipelines, transmission costs consist predominately of fixed costs. From 0.04¢ to 0.05¢ per kilowatt-hour per 100 miles, appears to be a fair example of high-voltage, large power transmission costs in Canada.

Bituminous coal is still the principal source of energy on this continent. Much of the coal now used is moved by rail transport, but, because rail routes are often circuitous, at relatively high freight rates, representative

rates for the transport of bituminous coal by rail range from 70¢ to 80¢ per short ton per 100 miles. Waterborne movement of coal, where possible, has many of the attributes of the transport of oil by tankers, and by large colliers the cost per 100 miles lies between 25¢ and 30¢ per short ton.

Table 1

COST OF TRANSPORTING ENERGY

Form of energy	Transmission method	Distance (miles)	Unit	Cost per 100 mi. (cents)	Conversion factor to B.t.u.'s[a]	Cost equivalent[b] cost/ton/ 100 mi. (cents)
Petroleum	Super-tanker	coastwise	Bbl.-34° gravity	1.0 to 1.5	6,000,000	4.5 to 6.7
Petroleum	30-in. dia. pipeline	2,000	Bbl.-34° gravity	2.0 to 3.0	6,000,000	9.0 to 13.5
Natural gas	34-in. dia. pipeline	2,000	thousand cu. ft.	1.1 to 1.6	1,050,000	28.0 to 40.8
Electric power	high tension line	400	k.w.h.	0.04 to 0.05	3,412	316.5 to 395.5
Bituminous coal	railroad	1,500	short ton	70.0 to 80.0	27,000,000	70.0 to 80.0
Bituminous coal	collier	coastwise	short ton	25.0 to 30.0	27,000,000	25.0 to 30.0

[a]These figures do not take into account relative efficiency in use.
[b]27 million B.t.u. or one short ton of coal equivalent.

The relationship between the cost of transmitting different forms of energy by various methods of conveyance are set out in the accompanying table. It shows that:

(a) oil can be transported more cheaply either by tanker or by large diameter pipeline than can the alternative forms of energy;

(b) coal moved coastwise by collier is next in line followed by natural gas. In order to make a fair comparison between these two forms of energy, certain other costs must be added where coal is concerned. This is because the solid fuels usually involve costly handling operations between the docks and the consumer's stockpile. Also, some allowance should be made for the additional costs involved in carrying coal inventories—outlays of a type which do not arise in the case of natural gas;

(c) coal moved by rail costs almost three times as much as by water;

(d) electric power is the most expensive of all these forms of energy to transport. Sight must not be lost, however, of the fact that electricity is not a raw product like crude petroleum or coal. It is already available in a highly processed, and hence more desirable, form;

(e) conversion efficiencies in present-day thermal plants vary. Thirty per cent might be taken as a good round figure for future stations in the Maritimes. Therefore, in assessing the relative advantages of pithead as opposed to load centre power generation, using coal as the fuel, high tension line costs should be divided by a factor of just over three. The conclusion, then, is that the costs of transporting energy as electricity or in the form of coal by rail are comparable. However, in circumstances where the rail route tends to be more circuitous, a new main transmission line direct to the load centre may well turn out to be the more efficient of the two.

A NOTE ON THE WORLD PRICE OF OIL

In studying the world's oil trade, one cannot help but be impressed by the growing importance of overseas sources of supply. Shipments first from South America, and more recently the Middle East have come to dominate the world's international trade in crude oil. Though production off this continent has increased rapidly, reserves have risen in even more spectacular fashion. Faced with what in other circumstances would be a loss of domestic markets, holders of mineral rights, independent producers and certain of their larger American oil companies have pressed consistently for import controls. As a result, foreign produced crudes entering the United States have been subject to volume quota restrictions, a form of protection which has been particularly effective since oil reached a condition of over-supply in 1954.

Import limitations, voluntarily applied, have succeeded in maintaining the price of crude oil relative to other commodities. Indeed, in recent years, there is some indication that the return per barrel at wellhead in the United States has risen more rapidly than wholesale prices generally. Forward looking appraisals released periodically by government and other agencies have been used to adjust the United States output to United States demand. New investment in exploration and development has also been geared more closely to domestic requirements. Production in the United States, because of this and because of the security offered by import limitations, has continued to run at between 80% and 90% of capacity. Bolstered in this way, the return to producers in the United States has been maintained at a level above that which might otherwise have resulted in greater competition from South America and Middle Eastern sources of supply.

The maintenance of a high price level is not commonly regarded as an end in itself. Rather it is seen as providing an incentive (and a particularly effective one) whereby additional reserves internal to the North American continent might be proved up. It is consistent with the short-term strategic objective of having adequate supplies of domestically produced oil on hand in the event of an emergency. To the extent that the producers in Canada and Venezuela also enjoy preferred entry into the United States market, they also can be said to benefit from this increasingly arbitrary division in the world's oil trade.

Outside of the United States production costs and wellhead prices are not necessarily related one to the other. The main reason for this is that the delivered price of oil is still based essentially on quotations posted daily,

weekly and monthly in the Texas Gulf area. This, plus the cost of transportation to the market, still largely determines the laid down price of oil. Hence consumers in Western Europe, though they are much closer to what is now regarded as the world's principal sources of supply—the Middle East—are still having to pay a good deal more for their crude oil and refinery products than would be the case were the unfettered forces of supply and demand permitted to operate on a worldwide scale.

There is some indication that the historical tie in price which has existed between those prevailing in North America and quotations elsewhere is beginning to weaken. It is interesting to speculate as to what might happen were one or more new sources of supply to be developed, and competition for the European and other Eastern Hemispheric markets to be intensified. In all probability the world price of oil would fall; either that or remain relatively stable as average costs and wellhead returns rose in North America. Consumers, to the extent that their supplies were not impeded by United States import restrictions, would benefit. It could mean the competitive position of imported oil would be strengthened in eastern Canada.

In order to lend further credence to the view that world oil (and hence world energy) prices may, on balance, tend to decline rather than rise over the next 20 to 30 years, the following quotations have been lifted, quite liberally, from a recent report prepared by the United Nations Secretariat for the Economic Commission for Europe, *The Price of Oil in Western Europe*.[1]

Major Shifts in Trade in Oil

"The present geographical origin of the petroleum products consumed in western Europe is very different from that of pre-war days. There have been two major changes. The first is the development of refinery capacity in western Europe. Before the war western Europe's imports of oil consisted chiefly of refined products, with imports of crude for domestic refining playing a smaller role. Since then the balance has swung completely round and it is refined products which are now the marginal import. This means that the price of crude oil is of much more direct interest to western European countries than it was before the war. The second major change is in the origin of western Europe's crude oil supplies. Before the war, some 40% of these came from the western hemisphere. Today, an overwhelming proportion of its much larger imports comes from the Middle East. The greater direct interest which western European countries now have in crude oil prices is therefore essentially in the price of Middle East crude oil.

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[1]Prepared by the Secretariat, Economic Commission for Europe, United Nations Document No. E/ECE/205, Geneva, March, 1955.

"These two changes in western Europe's position are only special facets of a general change in the pattern of world production and trade in crude oil and products. The first feature is the movement of refining capacity from the centres of crude oil production to those of refined products consumption, a shift dictated by both strategic[2] and balance-of-payments interests. The second feature is the great rise in crude oil production in the Middle East, which has in large measure dried up the pre-war flow of crude oil from the western to the eastern hemisphere. From the figures for reserves which are also shown, it may be concluded that there is nothing transient in this change. There has in fact been a circular change in the centre of gravity of world oil.

"These great shifts in the structure of production and trade, which have accompanied the continued rise in world output and reserves, might be expected to have important repercussions on the structure of relative prices in different parts of the world. As long as western Europe derived most of its oil supplies, both of crude petroleum and of finished products, from the western hemisphere, prices in Europe were bound to reflect those in its principal supplying area, plus transportation costs. Now, however, the eastern hemisphere is virtually independent of the western for supplies of both crude oil and products, and western Europe draws most of the crude oil for its own greatly expanded refining capacity from low-cost Middle Eastern sources. Nevertheless, prices of finished products in the main consuming centres of western Europe appear to bear about the same relationship to those in the United States as before the war, while the delivered price of its crude petroleum input, though now somewhat below rather than above corresponding prices in the United States, is still closely linked to them at a level which does not adequately reflect the switch to cheaper producing sources.

The Price of Middle East Crude Oil to Western Europe

"Throughout its history, the f.o.b. price of Middle East crude oil has been closely linked, though in a way which has changed with time, to that of crude oil in the United States. Until the end of the second World War, public quotations of prices at producing centres ("posted prices" as they are called in the trade) were made only in the United States. The price at which Middle East oil was sold was that needed to produce a delivered price, at the going freight rate, identical with that of oil from the Texas Gulf in the market to which the sale was being made. In other words, the effective f.o.b. price or "net back" for Middle East oil varied with its destination. F.o.b. prices first began to be posted in the Persian Gulf soon after the war at a level, allowing for quality differences, virtually identical with those in the Texas Gulf. Early in 1948 a gap between the two price

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[2]Since there are alternative sources of supply for crude oil, any country achieves greater security in oil supplies if its refineries are located at home.

levels developed which widened by successive stages until late in 1949, since when it has been constant.

"This developing relationship between United States and Middle East f.o.b. prices is sometimes explained as conforming to the laws of a normal competitive market. In such a market only one delivered price can be charged at any particular point for a homogeneous commodity, whatever its geographical origin, and in a unified and competitive world market suppliers will not be able to discriminate in their f.o.b. prices between different points in the market. In such circumstances there is one and only one structure of prices which is in conformity with the conditions of supply and demand at any moment. When, as with oil, transport costs are heavy in relation to the value of the commodity, the relation between f.o.b. prices in different producing centres will depend on the location of the frontier of competition between them.

"The explanation offered for the present price of Middle East oil relative to that of United States oil is as follows: crude oil from the Middle East now meets that from the Texas Gulf in the markets of the eastern seaboard of the United States. Its f.o.b. price can, according to this view, be no more and no less than is needed to yield a delivered price in those markets equal to that of American oil. This means that the f.o.b. price in the Middle East tends to fall below that in the Texas Gulf by an amount roughly equivalent to the difference in transport costs from the two producing centres plus the United States duty on foreign oil.

"The history of crude oil prices over the last twenty-five years is interpreted by similar reasoning as the natural result in a normal market of the gradual westward movement of the frontier at which Middle East and western hemisphere crude oils met. The position up to the end of the war, when f.o.b. prices were posted only in the Texas Gulf, is seen as reflecting a situation—which once, in fact, existed—in which the western hemisphere supplied, at least marginally, all markets. On this line of argument, the posting of equal f.o.b. prices in the Texas Gulf and the Middle East, which was the next stage, implied a movement of the frontier to a point at which transport costs from the two centres were identical, and the widening gap from 1948 to 1950 sprang from the advance of the boundaries of the "natural market" for Middle East oil across the Atlantic. [3]

World Cost-Price Relationships

"In a competitive market the margin between price and cost of production would not vary too widely between different producers or different

[3]Venezuelan prices are explained by similar reasoning. The eastern seaboard of the United States is the main market for this oil and the shipping ports of the Texas Gulf and Caribbean are roughly equidistant from New York. Hence the f.o.b. price of Venezuelan crude tends to differ from that of American only by the amount of U.S. import duty.

centres. If in such a market wide variations in profit margins did exist at any moment, they would be expected to stimulate the growth of low-cost and the shrinkage of high-cost production until, in the long term, the disparities were eliminated. In the oil industry, however, such disparities are large and persistent, both as between the United States and other crude-oil-producing centres and within the United States itself.

"The major cause of this dispersion is the geological accident that the productivity of wells varies enormously from field to field and country to country. In the United States, average output per well in 1950 was only some 11.6 barrels a day or 31 barrels if stripper wells[4] are excluded. In Venezuela, by contrast, the daily average was over 200 barrels and in the Middle East some 5,000 barrels, with production from some Kuwait wells rising as high as 9,000 barrels per day.

"The effects on relative costs of such differences in productivity are in some measure offset by differences in the cost of drilling wells. Drilling costs per foot in Venezuela appear to be over twice as high as in the United States and those in the Middle East can not be much smaller. Moreover, the need to provide public service and ancillary facilities, which in developed countries are a charge on the State, before exploitation can begin also helps to swell the costs of production in under-developed countries. Neither of these factors, however, does more than modify somewhat the enormous cost advantage which geological factors have conferred on the Middle East.[5]

"It is unfortunately impossible to complement these somewhat qualitative indications by any systematic cost or profit comparisons. Published data are scanty and the comparability of the accounting conventions employed is frequently open to question. The average cost of producing crude oil in Bahrein was estimated to have been about 10 cents per barrel in 1945.[6] Average costs for the United States as a whole in 1941 were some 76 cents per barrel and those for the east coast region nearly $1.50.[7] There can be no doubt that the present disparity between United States and Middle East costs exceeds the f.o.b. price differential.

"This is confirmed by the profit per barrel currently being earned on Middle East oil. Total payments in respect of taxes and royalties by Aramco to the Government of Saudi Arabia amounted in 1952 to $212 million.[8]

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[4]These are wells which are approaching the end of their useful life.

[5]Moreover, most of the wells in the Middle East flow adequately under their own pressure, so that costs are to this extent further reduced.

[6]25 cents if royalties are included. See *Petroleum Arrangements with Saudi Arabia,* proceedings of a special committee of the U.S. Senate (80th Congress) investigating the national defence programme.

[7]See *Report on the Cost of Producing Crude Petroleum,* United States Tariff Commission, Washington, December 1942.

[8]See *Joint Oil Producing Ventures in the Middle East*: A submittal by the Standard Oil Company (New Jersey) to the Attorney-General's National Committee to study the Anti-trust Laws, December 1953.

Since, under the existing agreement, such payments represent 50 percent of the net profits realized on crude-oil production, net profits must have been in the neighbourhood of $425 million, on a total production in that year of 300 million barrels. In other words, with crude oil selling at $1.75 per barrel, a net profit in the neighbourhood of $1.40 per barrel was being earned.[9] Although comparable figures for the United States are not available, the average profit margin certainly falls well short of this figure. The rate of return on capital invested must show a still greater disparity in view of the enormous difference between the productivity, in barrels per day, of wells in the Middle East and the United States to which reference has already been made.

"All these comparisons between the Middle East and the United States are in terms of averages, whereas what is required to demonstrate a divorce between price/cost comparisons and output decisions are data showing the persistence of wide disparities between prices and the cost of an additional unit of output in the different centres. While no such data are directly available it may safely be inferred that comparison in such terms would reveal even more striking differences in profit margins. It was found in the enquiry for 1941 already referred to that the dispersion of the average costs at wellhead for the five large producing regions of the United States ranged from plus 50 percent to minus 40 percent of the mean of 76 cents per barrel. The difference between particular fields and, *a fortiori*, individual wells must have been very much greater. In Saudi Arabia, by contrast, the average cost of 30-35 cents per barrel implied above is likely to be considerably greater than the cost of producing additional output, since exploration and general development costs, which are an overhead, account for a large proportion of the average cost.

"Incomplete though the facts be, it is evident that simple price/cost comparisons are not the effective regulator of either the volume or the geographical distribution of crude-oil production. The question is why, since Middle East production costs so little, it does not bring about a decline in price and drive out a large proportion of higher cost American production. This problem requires a consideration of the way in which the distribution of output is effectively determined.

"A very large part of the total costs of oil production consists of the expenses of exploration and prospecting. Once a field has been discovered, the additional costs of bringing the oil to the surface—substantially the cost of drilling wells[10]—are relatively small. So long, therefore, as the individual

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[9]The figures given in the 1952 Oil Agreement between Iraq and the Iraq Petroleum Company, which are quoted below, imply that costs of production per barrel are now some 25¢.

[10]The cost of pumping has to be added when a field does not yield adequately under its own pressure. When oil is discovered in underdeveloped areas, very large sums are also involved in developing ancillary public service and transport facilities. But this expenditure, like the cost of discovery, is an overhead cost.

producer knows that prices will not be affected by variations in his own output, there is an obvious incentive for him to recover his overhead costs as rapidly as possible by exploiting the deposit at the maximum rate. This is tempered only by the consideration that if the rate of extraction rises too high this will raise the costs of finally draining the deposit or, alternatively, reduce the quantity of oil which is ultimately recovered.[11] If a field is not in unified ownership even this latter restraint is absent; on the contrary, any individual owner runs the danger of having his oil drained away by others if he does not extract it as quickly as possible. In more rigorous language, for most producers at any given moment marginal costs will be very low and average costs falling over a very wide range of output. This means that if price is taken as given, there is an incentive to produce at or even above[12] the "maximum efficient rate".

"It is evident that, in the circumstances assumed, the result of the discovery of reserves significantly in excess of the current rate of consumption would be to drive down the price of oil to very low levels, perhaps not much exceeding the prime costs of its production. Moreover, the demand for crude oil is relatively insensitive in the short run to variations in its price, since it is a demand derived from that for refined products, which is itself rather insensitive in the short run. Hence the excess needed to provoke such an outcome need not be very large. Crude-oil production is, in fact, an important example of the well-known theorem that industries enjoying increasing returns will, if composed of a large number of autonomous producers, operate at a loss. The early history of the East Texas discovery, which at one point in the interwar period drove down the price of oil to 10 U.S. cents a barrel[13] and led to the employment of State forces to impose output control, provides a convincing illustration of the validity of the theorem.

"Under such conditions it is clear that exploration and prospecting would also be extremely irregular, being suspended when the price of oil fell to such low levels and resumed when the consequential fall in reserves and production sent prices soaring equally wildly upwards. A smooth rate of supply would, in short, be impossible in the conditions postulated.

"The response of the oil industry to these special features of its cost and demand conditions has been the development of a system for determining

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[11]For each field and well there is a so-called "maximum efficient rate" of extraction, an engineering concept which reflects the fact that if extraction proceeds too fast gas pressure will fall unnecessarily quickly, the flow of oil to the well bottom will be impaired and various other avoidable and undesirable modifications of the physical conditions of the field will be suffered.

[12]In so far as producers discounted future earnings, production, in the circumstances postulated, would systematically exceed the "maximum efficient rate" even if each deposit were under single ownership, and all the more so if producers had bearish expectations about future prices.

[13]The average price of comparable oil in the interwar period was roughly $1 a barrel.

prices and output in which considerations other than relative costs predominate.

"In the United States, the divorce of output decisions from the price/cost comparisons of the individual producers has come about by their transfer from private enterprise to State agencies. Oil conservation statutes have been passed in most of the oil-producing states which require or permit a public agency to fix ("prorate") the amount of oil produced by each field or well. Hence, the production of each area and its distribution between producing units within the area ceases to be a matter for private decision. In turn, the level of total output, and its distribution between states, is determined, within broad limits, on the basis of the monthly forecasts of demand, in total and for each state, which are supplied to the several agencies by the Federal Bureau of Mines. The Inter-State Oil Compact Commission provides a forum within which differences between states can be ironed out.

"In the rest of the world the same divorce of output decisions from individual price/cost comparisons takes place without the intervention and control of any public agency, because of the structure of the crude-oil industry. Given its position as, individually or in partnership with others, the agent responsible for exploiting the crude-oil resources of a whole country, any one of the eight major international oil companies is bound to be under pressure from the Government of that country to serve its best interests by capturing as large a share of the market as possible. In so far, however, as it has interests in other countries also, it is subject to similar pressure from them too. More generally, it cannot help but be aware of the nature and strength of such pressures in all countries. At the same time its position as, in effect, the major purchaser of the crude oil which it produces[14] gives it the power with which to resist and reconcile competing pressures.[15]

"In the absence of explicit co-operation, however, the separate assumptions of the individual companies as to the appropriate geographical pattern of oil production may not be identical, and this all the more since the underlying situation may change rapidly. However, so long as the companies are quickly responsive to changes in circumstances and their appreciations are not too far apart, there will emerge, through continuous testing of the possibilities of encroachment, a distribution of production between the producing countries outside the United States which accords at most times with the relative strength of the various forces at work. The rapid and continuous growth of world oil consumption referred to at the beginning

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[14]Because each of the major companies is a vertically integrated enterprise.

[15]The power which flows from control over transport, refining and distribution facilities and from the ability of the major companies to recognize common interests, was illustrated by the failure of Iran to sell any appreciable quantities of oil so long as its dispute with the Anglo-Iranian Oil Company continued.

of this chapter has, of course, greatly facilitated the reconciliation of the conflicting interests of different countries and the integration of new producing centres as they were discovered.

"With the arrival of Middle East oil at the shores of the United States (or even earlier, with the development of Venezuelan production) there arose the question of the proper division of the American market between foreign and domestic oil. Although there is at present no formal quantitative control over oil imports into the United States,[16] foreign oil is far from enjoying unimpeded entry into that market. The major United States companies producing crude oil abroad have recognized that violation of the widely quoted and generally accepted principle that foreign oils should "supplement but not supplant"[17] the domestic production of the United States would threaten to make irresistible the present very strong pressures for more stringent Federal restrictions on imports. This balancing of forces in determining the level of imports into the United States is symbolized in the term "industrial statesmanship", used by the Secretary of the Interior to describe the solution for the "problem" of oil imports.

The Price of Oil in the United States

"It follows from the foregoing that the determination of the United States price, which is the keystone of world-wide structure of crude oil prices is equally divorced from normal commercial forces. Since the volume of oil coming on to the United States market is, in effect, determined by administrative decision, and its price at any time will be that required to clear the market in the going state of demand, price is the product, at one remove, of administrative decision. Indeed, the definition of "waste" in conservation statutes as amongst other things "production of crude petroleum oil in excess of transportation or market facilities or reasonable market demand", itself implies a price assumption. The connection is, in fact, more intimate. The conservation authorities concern themselves not only with the total volume of output but with its distribution between producers with widely differing costs. But decisions as to this distribution can be effective only if the price which clears the market is one which covers the highest cost producers. In other words, decisions as to the volume of output depend in part on decisions as to its distribution. In the last analysis, in fact, the

[16]There is at present a tariff of 10.5¢ per barrel on crude oil (5.25¢ on the heavier crudes). Earlier the tariff was graduated and increased steeply if imports passed a quota which was related to the level of United States production.

[17]All sections of the oil industry in the United States have subscribed explicitly to the following declaration of policy by the National Petroleum Council: "The availability of petroleum from domestic fields under sound conservation practices, together with other pertinent factors provides the means for determining if imports are necessary and the extent to which imports are desirable to supplement our oil supplies on a basis which will be sound in terms of the national economy and in terms of conservation."

level of crude oil prices in the United States depends on the decision as to the level of costs beyond which the further working of a well or field shall be regarded as ceasing to serve the ends of conservation policy.[18]

"This note has examined the view that the price paid by Europe for Middle East oil is the result, over the long period, of the working of normal economic forces in a unified world oil market. It has been seen that the price is tied to that in the United States, with due allowance for freight charges. This price structure can be regarded as, in a sense, unified and internally consistent—if the existing distribution of production and trade is taken as given. The more important point is, however, that the distribution of production and trade is not itself closely responsive to differences in underlying price/cost relationships in the major producing centres. In this more fundamental sense the market could scarcely be regarded as unified nor prices as resulting from the free play of competitive forces.

"It is true that, so long as the eastern hemisphere was dependent on the western for supplies of crude oil, consumers in the eastern hemisphere could expect to exercise little weight in determining the price which they paid, and that this would depend on the price in the United States, however that might be determined. Now, the eastern hemisphere is self-sufficient in crude oil and, indeed, is exporting to the United States. Given, moreover, the narrow limits assigned to this flow, it is clear that the continued dependence of Middle East prices on United States prices cannot be explained in terms of underlying conditions of supply and demand.

"More specifically, the price of oil in the United States as well as the share of its consumption drawn from low-cost Middle East sources (about 2.3 percent in 1951-1953) can be viewed as by-products of its own national conservation policies. Under these conditions, the present limited flow of Middle East oil to the United States does not suffice to explain the continued linkage of prices in the two areas.

"The United States retains, of course, a direct interest in the price of Middle East oil, since a significant reduction might provoke, if not countered in some way, a vast increase in its imports and a consequent drop in its domestic oil prices which would be in conflict with the aims of the United States conservation policy. But even if such an increase in imports appeared

[18]The preceding analysis is, no doubt, a rationalization of the way in which conservation policy is, in fact, determined. The outcome depends on decisions by a number of separate and independent agencies and the processes of ratiocination which go on in each may well be less clear cut than is implied. This means only that the analysis is an over simplification, not that it is a misrepresentation. Whether the main consideration is the desire for full extraction from deposits already being worked, or alternatively the need to keep oil production generally sufficiently profitable to promote a high rate of exploration and prospecting for new fields is not relevant to this analysis.

imminent the United States Government would have remedies to hand by making explicit and formal the informal controls which are already applied.[19]

"Finally, the wide divorce which persists between prices and production costs in the Middle East suggests that, if this link were severed, the price charged on sales to European countries by the Middle East could be significantly lowered without adverse effects on the further development of its crude oil production."

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[19]One student of the problem has remarked: "It is doubtful whether the protection of the high-cost level of American prices can in the long run be achieved just by scaling up the prices from all sources in sympathy with price movements within the United States. No one in another country has the right to interfere with the domestic economic policy of the United States, but if the Americans wish to protect their industry they should do so at their border and not at source, as it were, in other people's countries." P. H. Frankel: "Market Price for the World", *Petroleum Times*, July, 1953.

EFFICIENCY IN USE

PART but not all of the energy potentially available in a given amount of fuel or water power can be put to effective use. Much is wasted at the source. Some is used up in transporting the remainder to the main areas of consumption. Processing to more usable forms as in oil refining or the generation of thermal power removes a portion of the supply which would otherwise be available to the ultimate user. Distribution and marketing also involve losses. And, finally, there is the question of efficiency in use. Rarely is the equipment employed by the average consumer better than 60% efficient. It may also be run for long periods of time at other than optimum conditions. Because of these various wastages and losses the quantity of raw energy entering the national energy system (input) exceeds the amount of energy effectively employed (output) by a considerable margin.

The ratio between the energy theoretically available at the primary level and the much lesser amount appearing as useful heat or work done is therefore a measure of over-all efficiency in use. Though a highly generalized concept it is useful when preparing estimates of future energy requirements. A changing supply "mix" can cause the over-all output-input ratio to change. So can a progressive shift in emphasis from one major use sector to another. Efficiency considerations have therefore formed an integral part of the methodology employed in the writing of this report.

Published data are available as to the efficiency in use of various fuels in particular types of equipment. This can be generalized to apply to individual industries and such major applications as residential and commercial space heating. As the primary and secondary fuel inputs of these various economic sectors are known, approximate national efficiency ratios can be devised by aggregating the various series to reach a national total.

During the course of this study, energy balance sheets descriptive of the Canadian supply-demand complex were prepared for Canada. (Two are are now avialable in the D.B.S. report *Energy Sources in Canada, 1948 and 1952*. A similar report covering the years 1926, 1929, 1933 and 1939 is also being prepared by the D.B.S. for publication.) These show the quantity of energy consumed in each use. Employing data provided by various Canadian, United States and United Nations authorities, average efficiencies were assigned to each energy source and weighted according to the quantities of fuel or power consumed in each category of use. Thus it was possible to arrive at estimates of the amount of energy effectively

employed industry by industry and major use category by major use category. National figures were obtained simply by totalling the various outputs. From this it was possible to calculate the "national efficiency factor" using the following equation:

$$\frac{\text{Energy put to effective use (Output)}}{\text{Gross energy supply (Input)}} \times 100 = \text{National efficiency factor}$$

Canadian data worked up in this way yielded a national efficiency factor series which improved with time. A hundred years ago less than 10% of all the energy consumed in Canada was actually put to effective use. Currently the figure is over 40%. This trend is further quantified in the following table:

National Efficiency Factor, Canada 1870-1953

	1870	1900	1926	1939	1953
Percentage	10	15	35	39	40

Similar calculations have been made for the United States. P. C. Putnam in his book *Energy in the Future*, published in 1953, reports that the over-all efficiency in energy use in the United States was in the order of 10% in 1900 and approximately 30% in 1950.[1] More recent analyses[2] indicate that the output-input ratio for the United States was in the order of 32% in 1953.

Putnam has also estimated the aggregate efficiency of use of energy for various other countries in the year 1950. That of the United Kingdom he placed at 24%. Next in sequence was the U.S.S.R. with 25%, Argentina with 21%, France with 20%, Germany with 20%, Japan with 13% and India with 6%. Putnam's world average figure at the mid-century mark was 22%.

Various reasons can be given as to why energy is put to use more efficiently in Canada. During the earlier years, space heating demanded a larger proportion of total supply than it does today. The conventional wood stove (as in many parts of Russia today) had an over-all efficiency in the order of 35%. This helped to raise the Canadian average. As most of the electricity consumed in Canada has been generated hydraulically this, too, has helped to maintain the over-all efficiency of the Canadian energy system well above the world average. Indeed, it is largely due to the fact that the United States depends much more heavily upon thermal generation (with its much lower efficiency of conversion) that the Canadian output-input

[1]See *Energy in the Future* by P. C. Putnam, consultant to the U.S. Atomic Energy Commission, D. Van Nostrand, Inc. Toronto, 1953.

[2]See *An Appraisal of Future Energy Supply and Demand in the United States,* Austin Cadle, Proceedings of the American Petroleum Institute, 1955.

ratio appears to advantage when compared to the national efficiency factor for the United States.

With the passage of time, comfort heating will decline relative to total Canadian energy requirements. Process heating (with a moderately high average efficiency factor) and mechanical work (with a comparatively low efficiency factor)[3] will rise relative to total supply. Gradually thermal generating plants will have to be built to supplement the electricity available from water power installations. Each of these influences will tend to depress, rather than raise, the national figure. Opposing this trend will be further improvements in the efficiency of many types of user equipment and better conservation practice at the resource level. Taking all of these various and conflicting tendencies into account an over-all national efficiency factor of 50% has been forecast for Canada in 1980.

Effective Contribution of Each Energy Source as a Percentage of Total Output

(Canada, 1926-80)

	1926	1939	1953	1980
Coal	68	54	32	13
Petroleum	6	14	39	34
Natural gas	3	4	5	25
Wood	14	11	5	1
Water power	9	17	19	23
Nuclear power	—	—	—	4
	100	100	100	100

Efficiencies of Energy Use

	%
Residential and commercial	
Coal and coke	50
Wood	35
Fuel oil, kerosene	60
Gas and l.p.g.	70
Electricity	100
Manufacturing and mining	
Coal and coke	60
Wood	40
Fuel oil (including residual)	65
Gasoline and kerosene	20
Gases (including l.p.g.)	70
Electricity	100

	%
Railways	
Coal	4
Fuel Oil	6
Diesel Oil	25
Electricity	100
Highways and air	
Gasoline and l.p.g.	20
Diesel oil	20
Jet fuel	20
Water transport	
Diesel oil	15
Fuel oil	9
Coal	6

[3]Putnam, in describing the U.S. energy system in 1947 indicates that the average efficiency of use in comfort heating in that year was 51%, for process heating, 30% and for work, 17%.

It is also possible, starting from the individual categories of use, to build up an output series which indicates the effective contribution of the different fuels and water power to the Canadian energy system. The preceding table shows (in contrast to the input tabulations appearing in the summary and at the end of Chapter 3 of this study) that hydro-electricity is expected to become one of the (if not the) most effective sources of energy in Canada 25 years from now.

The various efficiency factors employed in the foregoing calculations are as follows. They are similar to those used by N. B. Guyol and quoted in *World Energy Requirements* and published in the *Peaceful Uses of Atomic Energy—Proceedings of the International Conference in Geneva, August, 1955,* Vol. I. They measure what Putnam refers to as the "technical" efficiency.[4]

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[4]Putnam also refers to what he calls "economic" efficiency. This concept has been most thoroughly discussed by Ayres and Scarlott in *Energy Sources, the Wealth of the World* as "energy-system efficiency". This includes all energy consumed in producing, processing, and transporting the energy as well as the efficiency of the unit in which it is finally consumed. Thus of 100 gallons of oil in the ground, only five actually reach the road as "useful work".

Appendix E

UNITS OF MEASUREMENT

Coal, oil, natural gas, fuelwood, water power and nuclear energy have two things in common: (a) they are potential sources of heat, and (b) they are each potential sources of electricity or power. In order to compare their contribution one with the other (or to add their contributions one to the other), it is necessary to quantify the amounts of heat or the amounts of power which can be obtained from a standard physical unit of each of the commodities involved. If heat content is to be measured, the B.t.u. or calorie can be taken as a common denominator. If their power contribution is to be assessed the kilowatt-hour is usually the common unit employed. Throughout this study the B.t.u. has been employed in the calculations. Had one of the other units been chosen identical comparative results would have been obtained.

While the calculations were carried out in B.t.u.'s the results were presented textually in terms of tons of coal equivalent. The objective, in this case, was to assist the reader in comprehending the very large amounts of energy involved. Throughout, one ton of coal equivalent refers to the contribution of any one source (or combination of sources) of energy which was theoretically capable of providing the same amount of heat energy as one short ton of high-grade bituminous coal. Though expressed in a different fashion numerically it therefore had a potential heat yielding capability of 27 million B.t.u.'s.

Coal, crude oil, unprocessed natural gas, water power and fuelwood are referred to as primary forms of energy. Manufactured products obtained by processing or converting the primary supplies to other and often quite different commodities like coke, manufactured gas and thermal electricity are classified as secondary sources. This distinction must be made if double counting in the energy supply stream is to be avoided.

Excluded from this study is the energy contribution (as work) of draft animals and the human population. Currently they contribute less than 1% of all energy utilized in Canada. Other resources which have also been excluded because of the minor role which they play are wind power, farm wastes and explosives.

There is still the matter of converting heat to electrical energy and vice versa. One kilowatt-hour is physically equivalent to 3,412 B.t.u.'s. This conversion factor can, therefore, be used to determine the annual B.t.u. (or tons of coal equivalent) contribution of water power.

It is common practice in the United Kingdom and the United States (where thermal stations generate most of the power supply) to make this conversion with a view to indicating the tonnage of fuel which would actually be required to produce an equivalent amount of electricity. Because the efficiency of conversion is high (*i.e.* 90%) in water power stations and much lower in thermal power plants (25% to 35%) this results in an inflated (about three times) measure of the primary energy actually available as water power. Because of the much greater importance of hydro electricity in Canada's energy supply complex (and also because this inflationary procedure deviates from a strict interpretation of energy inputs and outputs) hydro-electric power has been given full status as a primary energy source in this country. Its higher efficiency in use, meanwhile, is recognized in the accompanying analysis of effective outputs.

The conversion factors employed for each individual commodity are as follows.

Energy Conversion Factors

Commodity	Physical unit		B.t.u.
Coal			
bituminous	one ton	=	27,000,000
anthracite	"	=	26,000,000
sub-bituminous	"	=	19,000,000
lignite	"	=	16,000,000
coke	"	=	25,000,000
Crude oil	one barrel (35 imperial gallons)	=	5,800,000
Natural gas liquids	"	=	4,000,000
Gasoline	"	=	5,200,000
Diesel fuel	"	=	5,800,000
Fuel oil	"	=	5,800,000
Residual oil	"	=	6,000,000
Petroleum coke	one ton	=	30,000,000
Natural gas	one cu. ft.	=	1,000
Manufactured gas	one cu. ft.	=	550
Water power	one k.w.h.	=	3412.
Fuel wood	one cord	=	20,000,000
Lubricants and other (non-fuel) derivatives of petroleum	one ton	=	30,000,000

Appendix F

STATISTICAL TABLES

(Additional statisical data, basic to the study and not reproduced here, are to be found in the D.B.S. publication on energy. See Bibliography, Section A: Energy Studies, Canada.)

Table 1

CONSUMPTION OF ENERGY IN CANADA BY PRIMARY SOURCES 1900-55

B.t.u.'s $\times$ ***10***^{12}

Year	Coal	Petroleum	Water power	Natural gas	Wood	Total
1900	270	4	17	—	186	477
1910	676	19	17	2	247	961
1920	856	78	17	5	186	1,142
1926	863	125	38	20	200	1,246
1927	932	149	45	23	202	1,351
1928	915	178	52	24	205	1,374
1929	943	220	59	30	209	1,461
1930	892	212	59	31	220	1,414
1931	668	203	55	27	218	1,171
1932	620	177	55	25	177	1,054
1933	603	185	60	24	182	1,054
1934	707	196	72	24	186	1,185
1935	675	211	79	26	189	1,180
1936	738	223	85	30	195	1,271
1937	794	251	95	35	199	1,374
1938	708	257	89	35	200	1,289
1939	802	285	97	37	203	1,424
1940	917	319	104	43	210	1,593
1941	1,010	354	115	46	208	1,733
1942	1,143	337	128	48	212	1,868
1943	1,192	368	138	47	216	1,961
1944	1,191	405	136	48	210	1,990
1945	1,089	399	133	51	225	1,897
1946	1,144	506	140	51	221	2,062
1947	1,164	564	155	56	216	2,155
1948	1,261	617	157	62	210	2,307
1949	1,167	650	169	65	200	2,251
1950	1,188	786	183	75	190	2,422
1951	1,181	922	205	86	180	2,574
1952	1,102	995	208	100	170	2,575
1953	1,017	1,113	217	112	160	2,619
1954	862	1,175	230	133	150	2,550
1955	912	1,426	246	170	145	2,899

Table 2

CONSUMPTION OF ENERGY IN CANADA 1900-55

(source as percentage of total energy)

Year	Coal	Petroleum	Hydro	Natural gas	Wood	Total
1900	56.6	0.8	3.6	—	39.0	100.0
1910	70.3	2.0	1.8	0.2	25.7	100.0
1920	75.0	6.8	1.5	0.4	16.3	100.0
1926	69.3	9.9	3.1	1.6	16.1	100.0
1927	69.0	11.0	3.3	1.7	15.0	100.0
1928	66.6	12.9	3.8	1.8	14.9	100.0
1929	64.5	15.1	4.0	2.1	14.3	100.0
1930	63.1	15.0	4.2	2.1	15.6	100.0
1931	57.1	17.3	4.7	2.3	18.6	100.0
1932	58.8	16.8	5.3	2.3	16.8	100.0
1933	57.3	17.5	5.7	2.3	17.2	100.0
1934	59.7	16.5	6.1	2.1	15.6	100.0
1935	57.3	17.8	6.7	2.2	16.0	100.0
1936	58.1	17.6	6.7	2.3	15.3	100.0
1937	57.8	18.3	6.9	2.5	14.5	100.0
1938	55.0	19.9	6.9	2.7	15.5	100.0
1939	56.3	20.0	6.8	2.6	14.3	100.0
1940	57.6	20.0	6.5	2.7	13.2	100.0
1941	58.4	20.4	6.6	2.6	12.0	100.0
1942	61.1	18.1	6.8	2.6	11.4	100.0
1943	60.7	18.8	7.1	2.4	11.0	100.0
1944	59.9	20.3	6.8	2.4	10.6	100.0
1945	57.3	21.2	7.0	2.7	11.8	100.0
1946	55.5	24.6	6.8	2.4	10.7	100.0
1947	54.1	26.1	7.2	2.6	10.0	100.0
1948	54.6	26.8	6.8	2.7	9.1	100.0
1949	51.9	28.9	7.5	2.8	8.9	100.0
1950	49.1	32.5	7.5	3.1	7.8	100.0
1951	46.0	35.9	8.0	3.1	7.0	100.0
1952	42.9	38.7	8.1	3.8	6.5	100.0
1953	38.8	42.5	8.3	4.3	6.1	100.0
1954	33.8	46.1	9.0	5.2	5.9	100.0
1955	31.4	49.1	8.5	5.9	5.0	100.0

Table 3

SUPPLY OF COAL IN CANADA 1926-55

(millions of short tons)

Year	Production	Imports	Exports	Supply	Canadian production for Canadian use
1926	16.4	16.6	1.0	32.0	15.1
1927	17.4	18.7	1.1	35.0	15.9
1928	17.6	17.2	0.9	33.5	16.5
1929	17.5	18.2	0.8	34.9	16.4
1930	14.9	18.7	0.6	33.0	14.1
1931	12.2	13.1	0.3	25.0	11.7
1932	11.7	12.0	0.3	23.4	11.2
1933	11.9	11.2	0.3	22.8	11.5
1934	13.8	13.0	0.3	26.5	13.2
1935	13.9	12.1	0.4	25.6	13.3
1936	15.2	13.1	0.4	27.9	14.5
1937	15.8	14.7	0.4	30.1	15.2
1938	14.3	13.0	0.4	26.9	13.8
1939	15.7	15.0	0.4	30.3	14.9
1940	17.6	17.4	0.5	34.5	16.7
1941	18.2	20.4	0.5	38.1	17.3
1942	18.9	24.9	0.8	43.0	17.7
1943	17.9	28.1	1.1	44.9	16.3
1944	17.0	28.7	1.0	44.7	15.7
1945	16.5	25.0	0.8	40.7	15.2
1946	17.8	26.1	0.9	43.0	16.5
1947	15.8	28.9	0.7	44.0	14.7
1948	18.4	30.9	1.3	48.0	16.9
1949	19.1	22.2	0.4	40.9	18.1
1950	19.1	27.0	0.4	45.7	18.2
1951	18.5	27.0	0.4	45.1	17.6
1952	17.6	25.1	0.4	42.3	16.7
1953	15.9	23.3	0.3	38.9	15.2
1954	14.9	18.7	0.2	33.4	15.2
1955	14.6	19.7	0.6	33.7	14.0

Table 4

CONSUMPTION OF COAL IN CANADA BY PRINCIPAL END USE 1926-55

(millions of short tons)

Year	Space heating	Railways and bunkering	Manufacturing and mining	Colliery and other uses[a]	Coke making	Electric power	Total consumption
1926	10.0	10.0	7.1	1.2	2.9	0.5	31.7
1927	11.6	10.5	7.4	1.3	2.9	0.5	34.2
1928	8.9	11.6	7.6	1.2	3.2	0.5	33.0
1929	10.0	10.5	8.1	1.2	3.7	0.5	34.0
1930	11.5	8.9	7.3	1.1	3.2	0.5	32.5
1931	7.3	7.4	6.0	0.9	2.5	0.4	24.5
1932	7.6	6.4	4.7	1.6	2.2	0.4	22.9
1933	8.0	6.1	4.5	0.8	2.5	0.4	22.3
1934	9.8	6.7	4.9	0.9	3.1	0.4	25.8
1935	8.7	6.9	5.1	0.9	3.1	0.4	25.1
1936	9.6	7.4	5.1	1.3	3.4	0.5	27.3
1937	10.2	7.6	6.4	1.1	3.6	0.5	29.4
1938	8.6	7.2	5.6	1.3	3.2	0.5	26.4
1939	10.5	7.8	5.9	1.6	3.3	0.4	29.5
1940	10.6	8.7	7.3	2.5	4.1	0.5	33.7
1941	11.6	10.3	8.7	1.7	4.3	0.6	37.2
1942	13.2	11.3	9.8	2.8	4.5	0.7	42.3
1943	14.0	12.8	10.5	1.2	4.8	0.7	44.0
1944	12.4	12.7	10.9	1.7	5.3	0.8	43.8
1945	12.5	12.8	9.5	—1.0	5.1	0.8	39.7
1946	14.2	12.2	9.0	1.6	4.5	0.8	42.3
1947	13.1	12.9	10.2	1.5	4.6	0.8	43.1
1948	13.5	12.9	11.1	3.6	5.2	1.0	47.3
1949	12.0	11.9	11.1	—1.3	5.2	1.1	40.0
1950	12.1	10.8	10.9	4.5	5.3	1.1	44.7
1951	11.1	10.9	10.9	4.9	5.3	1.1	44.3
1952	10.2	10.2	10.9	3.3	5.5	1.3	41.4
1953	9.7	8.7	11.0	1.0	5.7	2.0	38.1
1954	8.6	7.0 est.	10.0 est.	0.9 est.	4.7	1.6	32.8
1955	8.3	6.0 est.	10.5 est.	1.7 est.	5.5	1.8 est.	33.8

[a]Also includes inventory adjustment.

Table 5

SUPPLY OF ALL OILS IN CANADA
1926-55

(in thousands of barrels)

Year	Domestic crude production	Net crude imports	Net product imports	Total supply
1926	364	18,470	2,739	21,573
1927	477	21,350	4,754	26,581
1928	624	25,587	5,727	31,938
1929	1,117	31,457	6,691	39,265
1930	1,522	33,357	6,176	41,055
1931	1,543	30,230	4,956	36,729
1932	1,044	27,434	3,934	32,412
1933	1,145	28,934	2,429	32,508
1934	1,411	31,638	2,720	35,769
1935	1,447	33,967	3,066	38,480
1936	1,500	35,833	3,194	40,527
1937	2,944	38,915	4,242	46,101
1938	6,966	34,245	5,875	47,086
1939	7,826	37,095	6,288	51,209
1940	8,590	42,624	7,535	58,749
1941	10,134	46,790	5,095	62,019
1942	10,365	44,120	5,309	59,794
1943	10,052	49,754	5,273	65,079
1944	10,099	57,048	4,873	72,020
1945	8,483	56,806	3,809	69,098
1946	7,586	63,407	10,508	81,501
1947	7,735	68,447	23,365	99,547
1948	12,370	75,559	14,020	101,949
1949	21,404	73,948	20,749	116,101
1950	29,044	78,660	28,247	135,951
1951	47,616	82,942	31,052	161,610
1952	61,237	79,775	34,188	175,200
1953	80,899	76,970	37,128	194,997
1954	96,080	76,427	34,762	207,269
1955	129,440	71,844	36,654	237,938

Table 6

CONSUMPTION OF PETROLEUM PRODUCTS IN CANADA 1926-55

(in thousands of barrels)

Year	Motor gasoline	Aviation fuel	Railways	Marine	Residential and commercial	Manufacturing and mining	Other[b]	Refinery consumption and losses	Total
1926	8,600	—	—	—	—	3,450	412	1,564	14,026
1927	10,398	—	1,534	3,718	—	3,503	568	1,864	21,585
1928	13,823	—	1,874	4,000	1,265	4,017	523	2,265	27,767
1929	17,341	—	1,852	4,511	1,488	4,888	750	2,765	33,595
1930	17,192	—	2,113	4,483	2,125	4,696	637	2,798	34,044
1931	16,150	—	1,658	4,457	2,093	4,143	510	3,098	32,109
1932	14,435	—	1,641	4,572	2,343	3,644	786	2,697	30,118
1933	13,234	—	1,261	3,686	2,851	3,711	744	2,689	28,176
1934	14,989	—	1,468	4,200	3,136	4,101	927	2,666	31,487
1935	16,118	—	1,358	3,917	3,119	4,246	1,267	2,976	33,001
1936	17,619	—	1,502	4,775	3,197	4,668	1,276	3,272	36,309
1937	20,265	—	1,520	4,605	3,364	5,266	1,151	3,338	39,509
1938	21,998	—	1,487	5,007	3,403	5,257	1,058	3,509	41,719
1939	23,263	—	1,558	5,856	3,889	6,079	1,347	3,982	45,974
1940	24,857	351	1,599	7,102	4,288	7,976	1,321	5,180	52,674
1941	26,269	1,592	2,107	7,864	4,193	9,812	1,645	5,956	59,438
1942	23,439	3,342	2,123	6,832	3,544	10,377	1,722	5,528	56,907
1943	22,622	4,586	2,234	6,692	3,369	10,778	2,460	6,485	59,226
1944	24,438	4,096	1,732	8,734	3,581	10,972	3,911	7,434	64,127
1945	27,958	1,563	2,194	8,615	4,713	10,769	2,840	7,476	66,128
1946	34,646	850[a]	2,594	6,471	10,006	11,962	3,676	5,946	76,151
1947	39,188	900[a]	2,859	7,549	16,273	14,548	4,411	6,187	91,915
1948	42,408	951	3,382	7,653	17,036	15,674	4,409	6,541	98,054
1949	46,725	1,381	5,173	7,771	18,734	17,916[a]	4,491	7,211	109,402
1950	50,942	1,716	7,210	7,290	24,670	20,157[a]	5,043	8,292	125,320
1951	56,694	1,872	9,155	8,073	29,787	22,399[a]	5,061	10,513	143,554
1952	62,140	2,959	10,428	8,316	34,864	24,641[a]	6,242	11,194	160,784
1953	67,193	3,719	9,546	9,311	38,585	26,883	7,213	12,891	175,341
1954	70,116	4,289	10,145	8,001	47,508	24,319[a]	8,914	13,178	186,470
1955	75,823	5,813						14,916	

[a]Estimates.
[b]Other includes agriculture, electric power plants, materials used in coke and gas plants and unspecified.

Table 7

APPARENT SUPPLY OF NATURAL GAS IN CANADA, 1926-55

(in millions of cu. ft.)

Years	Total production	Imports	Exports	Stock changes	Apparent supply
1926	23,075	119	—	—	23,194
1927	29,182	104	—	—	29,286
1928	36,721	128	—	—	36,849
1929	80,744	133	—	—	80,877
1930	138,007	151	—	+ 692	137,466
1931	182,067	109	—	+1,704	180,472
1932	124,119	121	—	+1,562	122,678
1933	107,166	101	—	+1,670	105,597
1934	104,076	107	—	+1,646	102,537
1935	102,635	107	—	+1,508	101,234
1936	103,979	118	—	+1,451	102,646
1937	97,194	114	—	+1,444	95,864
1938	85,267	133	—	+1,415	83,985
1939	63,401	114	—	+ 158	63,357
1940	61,653	130	—	—	61,783
1941	75,060	172	—	—	75,232
1942	67,716	197	—	—	67,913
1943	63,816	232	—	—	64,048
1944	61,170	271	—	—	61,441
1945	60,310	346	—	+3,768	56,888
1946	58,382	368	—	+5,302	53,448
1947	61,979	433	—	+3,172	59,240
1948	70,673	404	—	+2,939	68,138
1949	76,371	1,263	—	+2,598	75,036
1950	84,797	3,254	—	+1,912	86,139
1951	94,964	3,699	—	+1,482	97,181
1952	105,364	5,982	8,145	+3,536	99,665
1953	125,626	6,097	9,629	+3,907	118,187
1954	150,398	6,236	7,148	+4,123	145,363
1955	191,119	11,166	11,360	+4,413	186,512

Table 8

NATURAL GAS CONSUMPTION IN CANADA, 1926-55

(millions of cu. ft.)

Year	Residential and commercial	Manufacture	Central electric stations	Mining and misc.	Field use	Field waste and other losses	Total
1926	13,000	3,000	—	5	2,282	3,867	22,155
1927	12,900	4,498	789	4	2,510	7,805	28,506
1928	14,200	3,692	438	4	2,771	14,138	35,242
1929	15,400	4,635	673	3	6,750	52,366	79,827
1930	16,900	3,771	385	8	5,053	108,630	134,747
1931	15,300	3,824	324	6	4,251	156,192	179,898
1932	16,300	3,208	304	4	2,328	100,699	122,843
1933	15,800	3,186	312	10	2,357	84,028	105,695
1934	15,000	4,061	316	17	2,831	80,914	103,138
1935	16,900	4,405	314	21	2,764	77,725	102,128
1936	18,800	4,810	—	59	3,929	75,866	103,466
1937	19,200	5,802	335	282	6,273	64,814	96,705
1938	19,000	5,776	310	26	5,716	51,823	82,650
1939	19,900	6,113	327	29	7,052	28,216	61,637
1940	22,000	9,959	301	51	8,553	20,421	61,284
1941	21,900	9,558	634	9	8,377	31,565	72,042
1942	23,200	11,488	—	980	8,926	22,018	66,613
1943	21,516	10,736	996	571	8,537	19,540	61,896
1944	21,977	12,498	1,120	1,070	9,525	16,103	62,294
1945	25,152	9,106	2,002	415	9,962	11,898	58,536
1946	25,233	8,745	1,459	252	8,607	10,481	54,778
1947	28,199	11,487	1,356	149	9,106	9,323	59,620
1948	30,824	12,825	1,740	244	10,094	12,069	67,797
1949	32,165	14,439	2,392	204	10,338	15,914	75,451
1950	40,004	17,897	5,299	247	9,630	16,975	90,053
1951	43,048	21,869	6,514	190	10,880	15,503	98,004
1952	43,328	22,677	4,765	177	12,923	16,678	100,550
1953	46,391	24,284	6,580	52	14,566	24,640	116,513
1954	56,864	30,275	9,585	383	15,624	29,663	142,393
1955	68,591	48,699	13,402	570	18,936	40,347	190,545

Table 9

TOTAL ELECTRICITY GENERATED IN CANADA, 1926-55

(millions of k.w.h.)

Year	Central electric stations			Industrial[a] generation	Total[b] Canada
	Hydro	Thermal	Total		
1926	11,911	174	12,085	567	12,660
1927	14,346	203	14,549	810	15,377
1928	16,106	231	16,337	1,153	17,509
1929	17,680	280	17,960	1,324	19,306
1930	17,749	345	18,094	1,358	19,468
1931	16,025	306	16,331	1,276	17,620
1932	15,724	328	16,052	1,388	17,453
1933	17,006	333	17,339	1,348	18,697
1934	20,817	380	21,197	1,544	22,749
1935	22,884	399	23,283	1,634	24,927
1936	24,933	470	25,402	1,686	27,099
1937	27,176	512	27,688	2,527	30,225
1938	25,691	463	26,154	2,439	28,603
1939	27,837	501	28,338	2,631	30,979
1940	29,537	572	30,109	2,943	33,062
1941	32,629	689	33,318	3,150	36,479
1942	36,583	772	37,355	3,642	41,007
1943	39,660	820	40,480	3,461	43,951
1944	39,553	1,046	40,599	2,962	43,571
1945	39,131	999	40,130	2,564	42,724
1946	40,692	1,045	41,737	2,914	44,663
1947	42,273	1,152	43,425	3,737	47,174
1948	41,070	1,320	42,390	4,862	47,262
1949	42,779	1,639	44,419	6,162	50,593
1950	46,624	1,870	48,494	6,530	55,037
1951	52,955	1,897	54,852	6,582	61,447
1952	57,802	1,607	59,409	6,685	66,094
1953	61,069	1,791	62,861	7,146	70,017
1954	63,932	2,004	65,936	7,539	73,488
1955	69,478	3,433	72,911	8,000[c]	81,000[c]

[a]Can be assumed to be predominately hydro power.
[b]Includes power generated by electric railways for use in their own operations.
[c]Preliminary figure.

Table 10

ELECTRIC POWER CONSUMPTION BY END-USES IN CANADA, 1935-55

(millions of k.w.h.)

Year	Pulp and paper	Primary iron and steel	Abrasives	Chemicals	Smelting and refining	Other manufacturing	Mining	Domestic service	Commercial[a]	Exports	Losses	Total consumption[b]
1935	10,592	321	286	1,199	1,073	1,919	1,025	1,770	3,045	1,365	2,319	24,914
1936	11,368	355	352	1,279	970	2,430	1,036	1,887	3,659	1,578	2,210	27,124
1937	12,037	573	419	1,507	2,604	2,281	1,503	2,007	3,073	1,847	2,372	30,223
1938	9,959	399	288	1,389	3,250	2,208	1,756	2,173	2,359	1,827	2,985	28,593
1939	11,084	529	280	1,547	3,493	2,497	1,761	2,311	2,550	1,913	2,993	30,958
1940	10,258	1,100	421	1,979	4,029	2,809	1,954	2,437	2,913	2,135	3,018	33,053
1941	9,209	1,493	587	2,433	5,942	3,466	2,081	2,582	3,213	2,360	3,102	36,468
1942	8,696	1,769	772	2,868	8,548	4,343	2,011	2,717	3,542	2,454	3,277	40,997
1943	8,039	2,018	917	2,808	11,280	4,550	1,895	2,844	3,594	2,545	3,451	43,941
1944	8,168	1,604	805	3,054	10,686	4,212	1,884	3,047	4,053	2,585	3,478	43,576
1945	10,855	1,628	712	2,306	6,756	4,092	1,869	3,365	4,975	2,646	3,506	42,710
1946	13,361	1,200	741	2,681	6,109	3,873	1,940	3,882	4,577	2,482	3,815	44,661
1947	12,289	1,708	832	2,815	8,056	4,496	2,121	4,383	5,536	2,067	3,742	48,045
1948	10,350	1,834	821	3,113	8,861	4,519	2,182	4,984	4,467	1,743	4,466	47,340
1949	11,746	1,878	719	3,092	9,070	4,461	2,294	5,679	5,342	1,757	4,573	50,611
1950	12,406	1,870	726	3,444	9,745	4,913	2,530	6,750	5,800	1,926	4,914	55,024
1951	13,164	2,396	1,121	3,905	10,618	5,528	2,830	7,726	6,072	2,376	5,707	61,443
1952	13,992	2,629	934	3,709	11,816	5,790	2,941	8,741	7,131	2,493	5,938	66,114
1953	14,715	1,928	1,030	3,970	13,087	6,197	2,854	9,878	7,738	2,427	6,364	70,188
1954	15,643	1,579	790	4,196	13,444	6,783	3,129	11,281	7,260	2,718	6,771	73,394
1955	16,214	2,219	1,024	4,400	14,936	7,035	3,230	12,760	7,512	4,433	7,294	81,057[c]

[a]Commercial: commercial light, street lighting, free services, municipal power and other industries.
[b]Includes imports.
[c]1955 is preliminary.

Table 11

CANADA PER CAPITA CONSUMPTION OF FUELS AND ELECTRICITY 1926-55

Year	Coal (tons)	Natural gas (000 cu. ft.)	Oil (bbls.)	Electricity (k.w.h.)
1926	3.3	2.3	1.5	1,352.0
1927	3.5	3.0	2.2	1,595.6
1928	3.5	3.5	2.7	1,780.3
1929	3.4	8.0	3.3	1,925.0
1930	3.2	13.2	3.3	1.907.1
1931	2.4	17.3	3.1	1,698.2
1932	2.2	11.7	2.9	1,660.6
1933	2.1	9.9	2.6	1,758.4
1934	2.4	9.6	2.9	2,117.9
1935	2.3	9.4	3.0	2,305.6
1936	2.4	9.5	3.3	2,473.9
1937	2.7	8.7	3.6	2,735.6
1938	2.4	7.4	3.7	2,564.3
1939	2.6	5.5	4.1	2,748.7
1940	3.0	5.4	4.6	2,988.7
1941	3.2	6.3	5.1	3,168.0
1942	3.6	5.7	4.9	3,518.7
1943	3.7	5.2	5.0	3,726.4
1944	3.7	5.2	5.4	3,647.4
1945	3.3	4.8	5.5	3,538.8
1946	3.4	4.5	6.2	3.633.5
1947	3.4	4.8	7.3	3,758.6
1948	3.7	5.3	7.6	3,685.7
1949	3.0	5.6	8.1	3,762.4
1950	3.3	6.6	9.4	4,013.8
1951	3.2	6.9	10.2	4,386.2
1952	2.9	7.0	11.1	4,580.3
1953	2.6	7.9	11.9	4,734.4
1954	2.2	9.4	12.3	4,900.0
1955	2.1	11.2	14.0	5.200.0

Table 12

WORLD PRODUCTION OF ENERGY, BY DECADES FROM 1860
(millions of tons of coal equivalent)

Year	Coal and lignite	Petroleum and nat. gasoline	Natural gas	Water power	Wood and its products	Total
1860	134	0.125	—	0.75	421	557
1870	207	1	—	1	439	648
1880	321	5	—	1	467	794
1890	487	14	5	2	493	1,001
1900	723	27	9	2	533	1,294
1910	1,091	58	20	4	595	1,768
1920	1,242	131	32	8	619	2,032
1930	1,278	265	72	16	643	2,274
1940	1,463	390	108	24	724	2,709
1950	1,567	700	261	42	722	3,292
1953	1,641	879	349	53	730	3,652

Table 13

WORLD PRODUCTION OF ENERGY, BY DECADES FROM 1860
(each source as a percentage of total production)

Year	Coal and lignite	Petroleum and nat. gasoline	Natural gas	Water power	Wood and its products	Total
1860	24.0	.2	—	.2	75.6	100.0
1870	31.9	.2	—	.2	67.7	100.0
1880	40.4	.7	—	.1	58.8	100.0
1890	48.7	1.3	.5	.2	49.3	100.0
1900	55.9	2.1	.7	.1	41.2	100.0
1910	61.7	3.3	1.1	.2	33.7	100.0
1920	61.1	6.4	1.6	.4	30.5	100.0
1930	56.2	11.7	3.2	.7	28.2	100.0
1940	54.1	14.4	4.0	.8	26.7	100.0
1950	47.6	21.3	7.9	1.3	21.9	100.0
1953	45.0	24.1	9.5	1.4	20.0	100.0

Table 14

GROSS ENERGY CONSUMPTION IN CANADA, UNITED STATES, AND UNITED KINGDOM 1926-55

(in millions of tons coal equivalent)

Year	United States	Canada	United Kingdom
1926	831	46.0	204
1927	807	50.0	212
1928	827	50.8	202
1929	878	54.0	210
1930	823	52.3	204
1931	694	43.3	190
1932	605	39.0	186
1933	624	39.0	186
1934	662	43.8	201
1935	705	43.7	204
1936	791	47.0	213
1937	840	50.8	221
1938	734	47.7	208
1939	796	52.7	215
1940	882	59.0	221
1941	983	64.1	219
1942	1,029	69.1	220
1943	1,123	72.5	215
1944	1,174	73.7	218
1945	1,163	70.2	207
1946	1,124	76.3	212
1947	1,211	79.7	216
1948	1,253	85.4	226
1949	1,164	83.5	231
1950	1,294	90.0	243
1951	1,358	95.9	252
1952	1,345	96.0	253
1953	1,386	97.8	255
1954	1,337	95.3	264
1955	1,468	106.9	267

Table 15

PER CAPITA ENERGY CONSUMPTION CANADA, UNITED STATES, AND UNITED KINGDOM 1926-55

(in tons of coal equivalent)

Year	Canada	United States	United Kingdom
1926	4.9	7.1	4.4
1927	5.2	6.8	4.7
1928	5.2	6.8	4.4
1929	5.4	7.2	4.6
1930	5.1	6.7	4.2
1931	4.2	5.6	4.1
1932	3.7	4.8	4.0
1933	3.7	4.9	4.0
1934	4.1	5.2	4.3
1935	4.0	5.6	4.3
1936	4.3	6.2	4.5
1937	4.6	6.5	4.7
1938	4.3	5.6	4.3
1939	4.6	6.1	4.5
1940	5.2	6.7	4.6
1941	5.6	7.4	4.5
1942	5.9	7.6	4.5
1943	6.1	8.2	4.4
1944	6.2	8.5	4.4
1945	5.8	8.3	4.2
1946	6.3	7.9	4.3
1947	6.3	8.4	4.5
1948	6.6	8.6	4.5
1949	6.2	7.8	4.6
1950	6.7	8.5	4.8
1951	6.8	8.8	5.0
1952	6.7	8.6	5.0
1953	6.6	8.7	5.0
1954	6.4	8.2	5.2
1955	7.0	9.0	5.3

Table 16

ENERGY CONSUMPTION PER UNIT OF NATIONAL PRODUCT FOR CANADA, UNITED STATES, AND UNITED KINGDOM 1926-54

(index numbers: 1926-30 = 100)

Year	Canada	United States	United Kingdom
1926	101	106	77
1927	101	103	103
1928	95	98	97
1929	101	99	99
1930	102	94	98
1931	97	87	92
1932	95	87	90
1933	103	94	84
1934	104	91	88
1935	96	88	86
1936	99	88	86
1937	97	89	89
1938	91	81	84
1939	93	81	82
1940	91	82	81
1941	86	77	75
1942	77	74	71
1943	77	69	67
1944	75	69	69
1945	75	69	68
1946	84	75	74
1947	87	84	75
1948	90	84	75
1949	86	73	73
1950	87	76	74
1951	87	77	74
1952	82	73	76
1953	80	71	73
1954	81	69	72

Table 17

RELATIVE PRICES OF FUEL AND POWER IN CANADA AND THE UNITED STATES FOR SELECTED YEARS 1900-55

(constant dollars[a])

Year	Coal Canada	Coal U.S.	Oil Canada	Oil U.S.	Natural gas Canada	Natural gas U.S.	Electricity Canada	Electricity U.S.
	(Dollars per ton)		(Dollars per barrel)		(Cents per k.w.h.)		(Cents per k.w.h.)	
1900	4.97	1.85	3.38	2.12	—	—	—	—
1905	3.74	1.76	2.50	1.03	—	—	—	—
1910	3.97	1.59	2.04	0.87	—	—	—	—
1915	3.44	1.63	1.99	0.92	26.0	—	—	—
1920	3.12	2.43	2.69	1.99	16.0	—	—	—
1925	3.66	1.97	3.67	1.62	39.0	9.1	—	—
1930	4.10	1.97	3.82	1.38	40.0	8.8	—	1.63
1935	4.19	2.21	3.34	1.20	53.0	7.3	.49	1.62
1940	3.75	2.43	1.57	1.30	39.0	5.7	.46	1.35
1945	3.94	2.91	1.55	1.15	24.0	4.6	.38	.88
1950	3.46	3.00	1.75	1.55	5.0	4.1	.26	.62
1955	3.77	2.80	1.40	1.63	7.0	6.5	.29	.53

[a]Current price at the mine or well divided by the wholesale index for all commodities (1926 = 100). Electricity prices are for large power category only.

Table 18

NET ENERGY CONSUMPTION[a] BY MAJOR END-USES CANADA 1926-54

(millions of tons of coal equivalent)

Year	Domestic and commercial	Transportation	Manufacturing and mining	Fuel industry, losses and miscellaneous	Total Canada
1926	16.8	11.5	10.5	4.3	43.1
1927	18.5	13.5	11.0	4.6	47.6
1928	16.5	15.4	11.3	5.3	48.5
1929	17.9	15.2	12.2	7.5	52.8
1930	19.3	13.7	11.2	9.1	53.3
1931	15.0	11.9	9.6	10.1	46.6
1932	15.2	10.6	8.9	7.6	42.3
1933	15.6	9.8	8.0	7.4	40.8
1934	17.5	10.9	8.9	7.4	44.7
1935	16.8	11.2	9.4	7.6	45.0
1936	17.9	12.3	10.1	8.0	48.3
1937	18.9	13.0	11.6	7.8	51.3
1938	17.5	13.1	10.8	7.1	48.5
1939	19.6	14.1	11.8	6.4	51.9
1940	19.7	15.7	14.8	7.3	57.5
1941	20.4	18.0	16.0	8.3	62.7
1942	21.7	18.6	18.8	8.1	67.2
1943	22.1	20.1	18.5	8.7	69.4
1944	20.4	20.6	19.1	9.6	69.7
1945	20.9	21.0	14.7	9.2	65.8
1946	23.4	21.3	21.8	8.4	74.9
1947	23.3	23.3	19.2	8.7	74.5
1948	24.1	24.1	22.3	9.8	80.3
1949	23.0	24.6	18.0	10.2	75.8
1950	24.6	25.5	23.8	10.8	84.7
1951	24.9	26.8	25.8	11.4	88.9
1952	25.4	27.8	25.1	12.3	90.6
1953	25.8	27.7	23.7	14.2	91.4
1954	26.9	26.6	21.2	13.7	88.4

[a]Excludes all raw material and other non-fuel uses.

Appendix G

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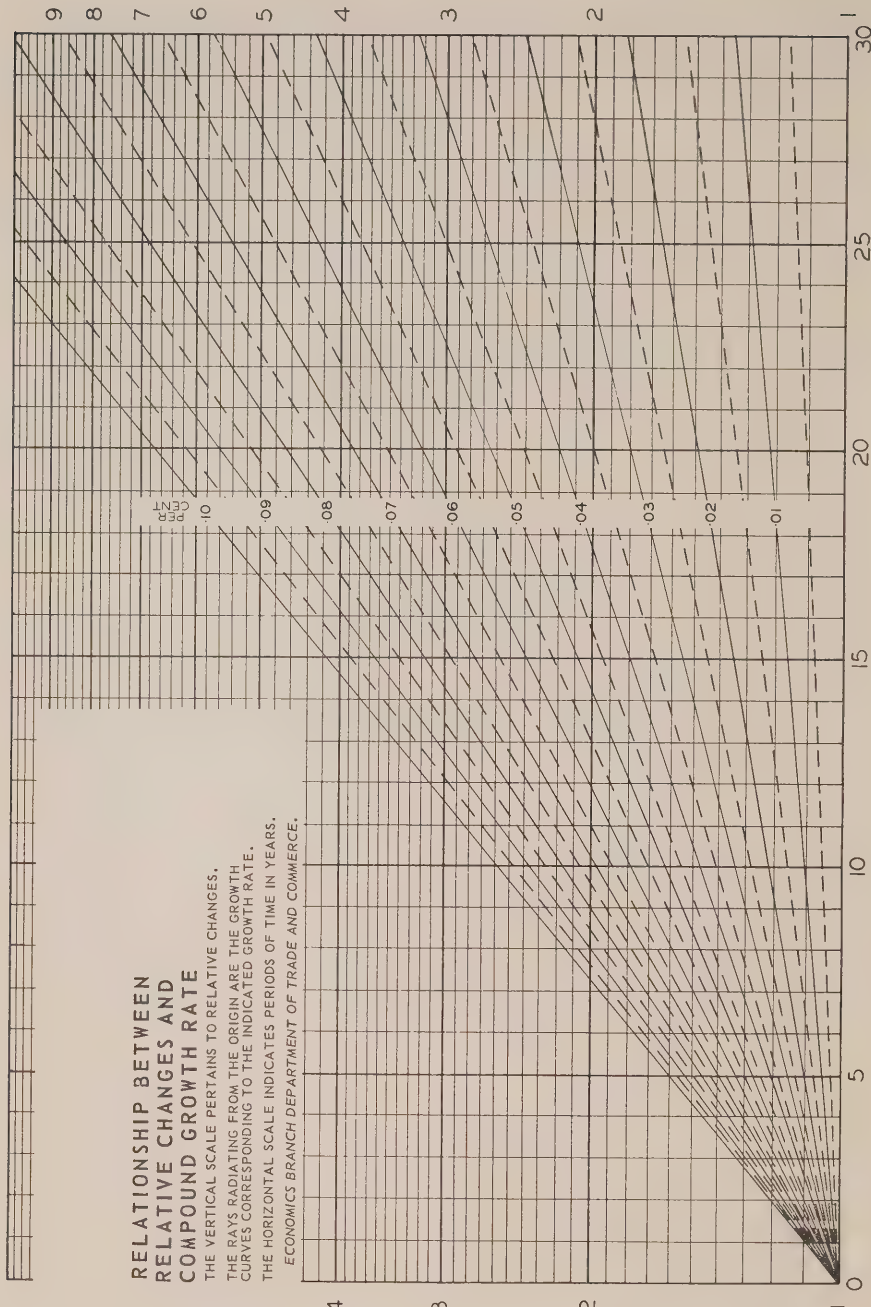
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